Spatial Planning and Sustainable Development

Ying Long
Enjia Zhang

Data Augmented Design

Embracing New Data for Sustainable Urban Planning and Design

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Preface

With the booming of information and communications technology (ICT), "Big data" such as mobile phone signal traces, public transportation smart card records, and "open data" from commercial websites and government data portals jointly promote the formation of the "new data environment," which provides a novel and supplementary perspective for planning and design and stirs up their methodology transition in essence. The concepts traditionally associated with healthcare architecture, such as evidence-based design (EBD), and other concepts like data-driven design and design with data are being integrated into urban planning and design. Quantitative data is encouraged to be used to find the right problems/opportunity areas, understand urban activities, and help decision-making and design process.

In such a condition, we have proposed a new planning and design methodology termed data augmented design (DAD) to highlight data (science) in and for design (Long and Shen, 2015).[1] Empowered by emerging big and open urban data, together with quantitative spatial analysis and statistical approaches and cutting-edge techniques like artificial intelligence and ubiquitous sensors, DAD provides a supporting platform for the whole (urban) design process, ranging from field investigation, existing condition analysis, future forecasting, scheme design, operation evaluation and feedback. It is hoped that the application of DAD in urban design practice could (and should) improve the scientific level of planning and design and inspire the creativity of planners and designers. Based on our understanding upon supporting tools for planning and design, the proposed DAD belongs to a new planning and design support form after CAD (computer-aided design), (S)DSS ((spatial) decision support system), GIS (geographical information system), and PSS (planning support system). In the past several years, we have been working on continually improving its application in design teaching and project practice. This book will discuss the main body of DAD and review its applications in design practice.

[1] Long Y and Shen Y (2015) Data Augmented Design: Urban Planning and Design in the New Data Environment. Shanghai Urban Planning Review, (02): 81–87 (in Chinese with English abstract).

DAD provides supporting tools covering the whole urban design process from investigation, analysis, and project design to evaluation and feedback. Typically, there are three main types of applications of DAD that aid site design—those that seek to understand the elements of the site, those that learn from other excellent cases, and those that embrace the most advanced technology and the future built environment. This book is organized at a conceptual and methodology level. Competitions and projects are divided into three parts according to their concepts and methods to adopt the DAD.

Part I is the overview of DAD, in which its definitions, dimensions, performance, and applications are introduced. Before that, conditions of contemporary cities in transition and some significant trends are illustrated to interpret the background of the proposal of DAD. Moreover, to better describe the merit of DAD in micro-space field, human-scale urban form and its applications in DAD are also presented in this part.

Part II is the first type of DAD applications, which aim to objectively understand the elements of a site to better design a site. In details, DAD can be applied to redevelopment-oriented design, which helps find problems via an existing condition analysis based on multidimensional data, and quantitatively evaluate the implementation of designs after site operation. Based on this method, three teams using DAD in urban design competitions have been supervised and received very good outcomes. In these three works, DAD as a methodology for urban design provided different methods for analyzing big and open data in different dimensions.

Part III is the second type of DAD applications that is learning from other cases to better design a site. In this part, DAD can be applied to the expansion-oriented design, which helps to extract spatial indexes from existing cases to form a classified "gene pool" for quantification and a reference index system for new designs. Based on this method, DAD has been successfully applied in the projects of the subcenter of Beijing and Xiong'an New District in China, proving the applicability of the type of DAD.

Part IV is the third type of DAD applications and the most future-oriented one. We describe it embracing advanced technologies and transitioning of cities to better design sites. As we illustrate in Part I, we live in an era of very rapid development and change that is driven by various forms of technologies, which have the potential to change the way we live, work, and play. Only by embracing the most advanced technology and transitions in cities can a better future be created. This concept reflects on two previous projects. One is about the future form of settlement and the other one focuses on the future form of an island.

Moreover, in the appendix, we have listed the related data for readers to better understand and utilize the framework of DAD, and we also collected the related research centers/labs and their representative projects for readers to gain further knowledge related to data science and data-driven urban design. Besides, in our opinion, educating graduate and undergraduate students, most of whom are the future urban planners, with a sense and knowledge of DAD is important as well for advancing its further application. As a result, established courses in colleges and universities around the world are also listed in the appendix as well.

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Contents

Part II Understanding the Elements of a Site to Better Design Sites

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Part I
Overview

Chapter 1
Cities in Transition

Abstract In the context of the fourth generation of the industrial revolution, emerging technologies have impacted almost all fields worldwide. Some changes are taking place in urban life and urban space under the influence of Information and Communication Technologies (ICTs). These changes will influence the way we understand cities and the generation of future-oriented urban designs. As a result, before we expand on the theme of this book "DAD (Data Augmented Design)," we describe a series of changes that are taking place in cities based on our long-term observations and literature reviews to help readers to aware that these emerging data reflect changes in cities. In this chapter, we discuss in detail the transformation of driving forces for the urban development, changes in products and services, and new features in urban space. These tremendous changes lead to new techniques and ideas that help us understand our cities and create futures. We look forward to a more quantitative and scientific approach to help understand changes that are taking place and are about to happen in our cities and to enrich current urban design methods. This chapter is the premise of the book's basic concept and thesis.

Keywords Disruptive technology · Urban space · Smart city · Digital activity · ICTs

1.1 Introduction

1.1.1 Emerging Technologies are Greatly Changing Urban Life

In the context of the fourth generation of the industrial revolution, emerging technologies have impacted almost all fields worldwide. The concept of the "smart city" is gradually being formed—using the Internet of Things, cloud computing, and other new generations of information technology (Anthopoulos 2017; Komninos

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and Mora 2018) to change the way governments, enterprises, and people interact with each other; to improve the efficiency of resource utilization, optimize urban management and services; and thus, to improve the quality of citizens' lives (Hollands 2008; Washburn et al. 2009; Dirks and Keeling 2009; Toppeta 2010; Scholl and AlAwadhi 2016; Lopes 2017). Digital twin systems that reflect the characteristics of a physical space and interact with a physical space in real time are also gaining attention (Batty 2018a, b). In practice, Germany's "Industrial 4.0," America's "Industrial Internet," China's "Made in China 2025," Singapore's "Smart Country 2025," South Korea's "U-City Plan," and other programs have been proposed to promote the development of intelligent manufacturing and the construction of smart cities. With the construction and development of smart cities and the applications of technology, the impact of emerging technologies on cities and society has also attracted much attention (Debnath et al. 2014). In Japan, "Social 5.0" emphasizes the symbiosis of humans with quality-of-life robots and artificial intelligence (AI), providing customized services for the complex and diverse segmentation needs of users. In China, President Xi Jinping's "smart society" in his report to the 19th National Congress emphasized that intelligent changes in people's productive lifestyles will more deeply impact all areas of society. These concepts illustrate that the people-oriented perspective of smart social activities is the main characteristic of smart cities.

In recent years, a book titled *The Inevitable* (2016) has attracted the attention of academia (Sayegh et al. 2016; Ivars-Baidal et al. 2019), in which Kevin Kelly forecasted the twelve technological forces that will shape the next 30 years. In his opinion, much of what will happen is inevitable, driven by technological trends that are already in motion. Cutting-edge technologies such as virtual reality in homes, an on-demand economy, and artificial intelligence embedded in everything we manufacture will have significant impacts on the way we work, buy, learn, and communicate with others. These deep trends, namely *Becoming*, *Cognifying*, *Flowing*, *Screening*, *Accessing*, *Sharing*, *Filtering*, *Remixing*, *Interacting*, *Tracking*, *Questioning*, and *Beginning*, are described in this book.

1. Becoming—everything will always be upgrading. We will not have time to master anything before it is displaced.
2. Cognifying—everything will be intelligent. Our new jobs will be to teach machines how to do our old jobs.
3. Flowing—everything will be copied. Time has shifted as well; the only things truly valuable are those that cannot be copied.
4. Screening—everything will be linked.
5. Accessing—no one owns anything.
6. Sharing—everything is shared. More artists, authors, and musicians are creating more books, songs, films, documentaries, photographs, artworks, operas, and albums every year.
7. Filtering—no one will have time to read anything. A wealth of information creates a poverty of attention. Our attention is our only valuable resource. While the cost of everything trends to zero, the price of human experience continues to increase.

8. Remixing—everything will be "redoable." Immersive environments and virtual realities in the future will be able to scroll back to earlier states.
9. Interacting—everything will be immersive. The best VR (Virtual Reality) triggers deep engagement with other people.
10. Tracking—everything will be recorded. We will record everything we do, all the time, for our entire lives, with total recall.
11. Questioning—everything will be improbable. Impossible things will actually happen all the time. The improbable will be the new normal.
12. Beginning—everything will be one, very large thing.

In this chapter, we also summarize some of the changes that are taking place in the world, especially in China today. These changes have led to changes in urban life from the perspective of technology and people's needs, which can be regarded as the most original motivation for us to propose Data Augmented Design.

1.1.2 Urban Space Also Changes with the Transition of Urban Life

From the perspective of urban planning and design, emerging technologies have a profound impact on urban life and thus on urban space. For example, the emergence of elevators made high-rise buildings possible, extending the vertical space of human settlements. The popularity of cars made the road network the skeleton of the city, expanding people's travel scale. Under the influence of the fourth generation of the industrial revolution, cutting-edge technologies, such as the Internet of Things (IoTs), self-driving cars, smart logistics, drones, virtual reality, and emerging concepts, such as the sharing economy and personalized activity and experiential consumption, have been changing the way we dwell, work, travel, and play. Eventually, the form or usage of urban space will also change. Traditional urban space is facing a transformation from conventional functions or forms to new ones, and at the same time, the new form of space organization is also gradually forming. We are expected to understand the influence of new technology on urban life and urban space and apply it to urban planning and design practice.

Some scholars have observed and concluded some changes taking place in urban life and space under the influence of ICT (Information and Communication Technologies)—virtualization (Konrad and Wittowsky 2018), mobility (Konrad and Wittowsky 2018; Ben-Elia and Zhen 2018), fragmentation (Lenz and Nobis 2007; Ben-Elia et al. 2014), and complexity (Shachaf 2008). The emergence of wireless network technology and the popularization of mobile information terminals have allowed people to enter a new era: the mobile Internet era. People's social and working habits are changing because of convenience (Rheingold 2002); that is, the advent of the mobile Internet makes it possible to conduct online activities anywhere, anytime in multiple ways. Activities that once required a fixed location and connection can now be conducted with greater flexibility, resulting in the ability of users to act and move more freely (Duffy 1997). Kenyon (2008) proposed the phenomenon of "multitasking" when he studied the influence of information and communication technology on residents' use of time and space. It is the "multitasking" of space and time that causes the "fragmentation" of space and time (Couclelis 2000). Moreover, the spatiotemporal boundary between residence, work, and leisure is becoming increasingly blurred. People can work in their leisure time or participate online leisure activities in their working time. The living place and working place are "integrating two into one" (Wei et al. 2013). These observations and conclusions provide us with inspiration for understanding urban space in a new way.

Next, we will describe a series of changes that are taking place in cities based on our many years of observation. Technological advances have given birth to the transformation of the driving force of urban development, which has led to the transformation of urban products and services, and the lifestyle of people has also changed. Urban space, as the carrier of urban life, also exhibits the characteristics of the new era. In this chapter, we will discuss in detail the transformation of the urban driving force (Sect. 1.2), changes in products and services (Sect. 1.3), and new features in urban space (Sect. 1.4).

In this context, urban research methods are also undergoing changes. The New Science of Cities was born, unlike the "regional science" embodied in the "old" urban science. The New Science of Cities uses newer technologies and tools that are evolutionary, complex and scientific, more discrete and bottom-up. At the end of this chapter, we will introduce "the study of urban discipline models based on in-depth quantitative analysis and data analytics"—The New Science of Cities. The New Science of Cities is the transformation of research methods and perspectives that led to the birth of the concept of Data Augmented Design, which is the topic and core of this book.

1.2 Driving Forces of Cities are in Transition

1.2.1 Smart Technology Supply

In the era of the mobile Internet, the driving forces of cities are in transition. AI, as technical support, disruptively defines this age and people's lives. Kelly (2016) noted that "it is hard to imagine anything that would 'change everything' as much as cheap, powerful, ubiquitous AI…. The arrival of artificial intelligence thinking accelerates all the other disruptions… it is the Ur-force in our future…. But a bigger payoff will come when we start inventing new kinds of intelligences and entirely new ways of thinking…." Since science and technology keep advancing, the concept of smartness or intelligence has been seen in every facet of urban life, and self-service stores, smart housing and communities, and other intelligent-technology-supported emerging products have greatly improved the convenience and working efficiency of human life as well as the diversity and accessibility of recreation. Smart people, smart mobility, smart economy, smart environment, smart living, and smart governance are six characteristics of smart cities (Giffinger et al. 2007).

However, these intelligent technologies are challenging human beings in unprecedented ways: currently, intelligent products, such as robots, are replacing human labor in low-tech, hazardous, or repetitive jobs and radically changing the climate of the workforce market in all industrial sectors. According to the report, *Jobs Lost, Jobs Gained: Workforce Transitions in a Time of Automation* released by McKinsey Global Institute (2017) up to 800 million individuals worldwide could be displaced by automation and will need to find new jobs by 2030. Of the total displaced, 75 million to 375 million individuals may need to switch occupational categories and learn new skills. In 2018, by analyzing the tasks and technologies of more than 200,000 workers throughout the world, PricewaterhouseCoopers Taiwan noted that the impact of automation on labor in all industries will reach 30% by the mid-2030s. The top three industries most likely to be impacted by automation are transportation and warehousing (52%), manufacturing (45%), and construction (38%).

Fortunately, the urban planner and geographer Batty (2018a, b) argues that "the real power of AI may well come from collaborations of man and machine, working together, rather than ever more powerful machines working by themselves." For instance, highly routinized short-term cycles can be predicted using AI, but "there are some hard choices involved in producing any plan for long-term development… and it is difficult to see the kind of design and decision-making involved in such planning being replaced by an AI…. Doubtless, the development of AI… will be useful in extending our understanding of how the high-frequency, real-time city actually functions, but it is difficult to see how such methods will ever dominate plan-making and design except in the very short term" (Batty 2018a, b).

1.2.2 Individual Demand for Instant Service

In addition to the smart transformation of cities caused by technology, in this era of rapid development, on-demand services are provided for people's real-time needs. Kelly (2016) argued that "our appetite for the instant is insatiable. The cost of real-time engagement requires massive coordination and degrees of collaboration…. Our lives are accelerating, and the only speed fast enough is instant… on average communication technology is biased toward moving everything to on demand. And on demand is biased toward access over ownership…. The expectation shifted so fast…. Now in the third age, we have moved from daily mode to real time." In China, this phenomenon is more prominent. People rely on a variety of Internet platforms to find products or services that meet their needs. Taobao and JD.com (Chinese version of Amazon) serve as e-commerce platforms to provide convenient shopping services for people and to deliver products to customers. Meituan and Ele, as typical O2O (Online to Offline) platforms, provide more timely service to customers. This individual demand for instant service will inevitably change citizens' lifestyle and ultimately change the functional distribution and urban pattern of the city. Sharing concepts that things are used but not owned also thrive in this context.

1.3 Transitions of Products and Services

As Batty (2013) said, "our technologies enable us to share and communicate at a distance…. The global world that has emerged is dissolving our reliance on material movements in favor of the ethereal and the social. Information is replacing as well as complementing energy." The physicality of flows between energy and information, manifested as materials, people, or ideas, exists in real Euclidean space but is often hidden from our immediate senses as in cyberspace or information space, which may have no geometric bounds. Based on these flows and networks, information products, durables and services in cities are also in transition.

1.3.1 Flowing, Fragmented, Crowd-Innovated, and Algorithm-Based Information Products

Over the past two or three decades, the age of information mobility and information spread among media has no longer relied on certain forms but has continued to change. This change will continue in the coming decades. Information products such as music, text, image, video, video game, website, software, and education have become an important part of our lives. Flowing, fragmented spreading, crowd-innovating, and reliance on algorithms are the four main characteristics of information products. These products often have four phases: mobility-fixed and rare physical products, massive and cheap flows that are spread, various information sharing flow services, and crowd-innovated flows that are open and always changing. Currently, sweeping information-flow services reduce the cost of information creation and enable ordinary people to act as agents of creating and spreading new information. In addition, information mobility is characterized by its fragmented spread, which responds to today's fast lifestyle but results in a decline in people's time and attention for in-depth reading, learning, and thinking. In addition, the decreasing cost of information creation shows the large commercial potential of crowd-innovated and sourcing information, encouraging the boom in nonelite music, films, books, and other art forms. Finally, the algorithm-based online platform is a characteristic feature of information mobility and influence. Today, people can easily obtain diverse instant information (such as information about real-time traffic, shopping and daily consumption, and tourist attractions) from these online platforms. Individuals become accustomed to or even overdependent on such information, which eliminates uncertainties and possibilities in one's daily life, shaping a city built on massive algorithm-processed results rather than individual preferences.

When people are highly reliant on Internet information and are guided by formulated algorithms, the urban physical environment changes dramatically.

1.3.2 Sharing, Service-Oriented, and Individual Requirements-Based Durables

As urban productivity increases, people's attitudes toward durable goods have also changed. The first change is the notion of "sharing," which means durables can be used but not necessarily owned. The idea of sharing has been introduced into all urban sectors over the past few years. The sharing economy is redefining individuals' lifestyle. People can exchange idle belongings, property, knowledge, and experiences on third-party platforms supported by information and communications technologies. Durables such as bicycles, automobiles, houses, offices, wardrobes, umbrellas, power banks, and washing machines are no longer simply supplied as commodities but as services. The sharing economy makes use-on-demand work rather than use-on-ownership. The second change is service-oriented industries. It is predicted that service industries will enjoy the greatest job market, which is dominated now by manufacturing industries. A service can be launched in many forms that can generate more added value than that of a product, which is why a large amount of money is pouring into service industries. In addition, this age of the Internet is characterized by increasing decentralization and the diversity of individual lifestyles. Beyond the homogeneous mass production in the Industrial Age, technologies such as 3D printing have considerably lowered manufacturing costs; social and economic development also increases suppliers' resources, which significantly encourages individual requirements-based durables. With technological supports such as high-speed computing and the IoT, cities in the future will not only meet citizens' basic living demands but also be able to radically improve resource allocation, spatial optimization, and citizen service by various real-time needs computing.

1.3.3 Home-Based, Self-Assisted, and Experience-Oriented Services

With the increasing demands in this era, the service industry also benefits from the mobile Internet, which has resulted in some new forms of services. Transportation development and advances in information and communications technology have together redefined the supply-demand relations of urban services: a more precise supplier-consumer matching mode is formed. Home-based services, such as food delivery, hairdressing, car washing, and cellphone repair, no longer require a physical store, which would vacate a large amount of urban space and encourage the emergence of living-commercial space in cities. All these changes have challenged the existing standards of urban spatial planning and construction. At the same time, many consumables and services are supplied to the public 24/7 in self-assisted forms, such as car washing, convenience stores, and book stores. In this way, services are available all day, saving labor costs and meeting people's immediate use-on-demand. Under the impact of the former two new service forms, services in traditional urban commercial spaces are also changing. Experience-oriented services are becoming an indispensable content in the physical commercial space. In other words, people pay more attention to experiences in the physical commercial space than to buying a specific product. Commercial space becomes a mixed place for a variety of activities, such as shopping, dining, entertainment, socializing, and education. These changes in products and services in cities not only efficiently save the time and travel costs of both suppliers and consumers but also help relieve traffic pressure by reshaping the flows of urban population and goods. In the future, urban planners, designers, researchers, and decision-makers are expected to respond to these changes.

1.4 Transitions of Urban Space

Cities are the earliest Internet of human beings. Compared with the countryside, the advantage of the city is its close-range and high-density interpersonal communication space, which brings about an efficient social organization structure. However, compared to cities, the Internet is a more efficient interpersonal machine that is constantly changing the spatial structure, resource allocation, functional layout, and information retrieval of cities.

1.4.1 Fragmented, Distributed, and Mixed-Use Urban Space Restructuring

On the macro scale, urban spatial structure is affected by flow and network. Batty (2013) argues that "there is little doubt that automation and instrumentation of retailing, transport, health, house buying and a variety of other traditional spatial behaviors is changing the way in which the city is structured spatially." The new location theory in the age of the Internet is gradually formed: physical spatial locations are changed or even disrupted by network-space locations, resulting in fragmented urban space patterns, the decentralized distribution of urban resources, and mixed urban land uses. In restructured urban spaces, the information hierarchy built on physical spaces is shifting toward a flat network-based structure. The Internet has given new opportunities for fragmented spaces deep in cities, freeing them from traditional space locations and re-establishing their appeal through online evaluations.

1.4.2 *Transition of Traditional Urban Space*

In the age of sharing, the traditional urban land-use mode would also be restructured or upgraded. Maker space, coworking space, and even co-living space have gained momentum over the past few years, which has accelerated the integration of teams and talent, innovation and entrepreneurship, online and offline resources, incubation and investment support, and so on. The Vanke Group first proposed the idea of a City Supporting Service Provider in 2014 to set up a new sharing business and the corresponding spatial forms by 2024 by integrating technological achievements. Vanke also completed the Design Commune in 2017 in Shenzhen, which is a mixed-use community for rent that combines working, living, and commercial spaces together for various needs in a resource-saving way. The low rent of the Design Commune has attracted a number of business groups, and many full-industrial-chain entrepreneurial neighborhoods of various sectors have been formed. The commune truly provides great convenience through home-workplace blending. Such practices are increasingly seen in metropolises in China and abroad. It is predicted that the current centralized, large-scale urban public spaces will be transformed into massive smaller spaces to serve micro-communities. Barcelona, for example, is a city where microsquares are ubiquitous and form a vigorous network of urban public spaces. Additionally, the number of public spaces with natural landscapes is increasing to meet people's desires to return to nature. Moreover, the commercial space is shrinking in size to serve chain business for self-assisted, scenario experience-based, and entertaining services.

1.5 Conclusions

Changes in lifestyle throughout human history are caused by changes in production modes, and changes in production modes are driven by technological innovation and productivity development. This chapter introduced two driving forces of cities in transition-smart technology supply and individual demand for instant service. These two driving forces have led to changes in products and services. We divide products and services into three types based on their forms, each of which presents multiple characteristics. The first type is flowing, fragmented, crowd-innovated, and algorithm-based information products, which are brought about by the progress of information and communication technology. The second type is sharing, service-oriented, and individual requirements-based durables, and this type is beginning to affect the way of life of urban residents more and more deeply. The third type is home-based, self-assisted, and experience-oriented services. These services could free people from many day-to-day nonprofessional jobs and provide people with more flexible time and place for entertainment, which is hoped to improve the quality of people's lives and rest time efficiency.

As mentioned above, cities are undergoing tremendous changes, so the science of urban space or urban problems should also take note, and new techniques and ideas are needed to help us understand our cities. According to Michael Batty (2013), as our technologies enable people to connect ever more easily and in many new ways, our understanding must be enriched by the studies of networks, interactions, connections, transactions, and every other possible way in which we are able to communicate with one another. Thus, the science of cities, as an interdisciplinary subject, studies different urban problems based on multidisciplinary research results. With the rapid development of new technologies and data, represented by computer technology and multicity data, the concept of a new science of cities proposed by Batty (2013) is a proposal for a new way to understand cities and designs not simply as places in space but as systems of networks and flows. This new science can be defined in a way that embraces the new data and provides a clear test for applications to problems relating to the big questions of our time, including inequality, aging, and the future of work, all of which have enormous spatial as well as temporal variations that need to be understood and explained (Batty 2019). In the book *The New Science of Cities*, Batty concluded with some models to understand the science of cities from six different perspectives that we think about cities, namely the growth, hierarchies, urban structure, distance, fractal growth and form, and urban simulation, and illustrated some good models of design that lead to decisions.

The introduction of the new science of cities has inspired the formation of the theme of this book: *Data Augmented Design* (DAD) methodology. We also look forward to a more quantitative and scientific approach to help understand the changes that are taking place and are about to take place in our cities and to enrich current urban planning methods. However, unlike the new science of science, DAD not only presents a series of tools for quantitative analysis and urban studies but also focuses on the transitions of urban space and urban life. The content in this chapter is the foundation of DAD, which in turn, reflects the important issues we apply in design and research.

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Chapter 2
Data Augmented Design (DAD): Definitions, Dimensions, Performance, and Applications

Abstract The emerging new data environment formed by big and open data provides a lens for a more detailed understanding and description of the entangling physical and social urban space. Since 2010, more than a dozen new labs, departments, and schools have been applying this new data in urban planning and design in various ways. In this context, this chapter reflects on a new urban design methodology—Data Augmented Design (DAD), first proposed in 2015, to highlight the use of data in design. This chapter introduces the profile of DAD by comparing its definition with related concepts such as Planning Support Systems (PSSs) and geo-design, depicting its framework and applications, and reviewing progresses regarding to the research network and annual conference, the DAD manual, courses and workshops, and the feedback from academics and practitioners. Its academic contributions and potential applications, as well as potential biases and future research avenues are also discussed.

Keywords New data environment · Big data · Design science · Urban design · Planning support system

2.1 Foundations and Prerequisites

2.1.1 Planning Support System as an Information Framework for Urban Planning

Planning Support Systems (PSSs) as sets of geo-information technologies are developed to embrace the available methods, techniques, and models developed in research laboratories to analyze spatial problems and to evaluate future options or project alternative scenarios (Geertman 2006). They were first described by Harris (1960) as a means of utilizing computer-based modeling and analysis instruments to support planners. Inspired by Harris, there was a growing effort to develop and

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optimize the frameworks and tools of PSSs. "SimLand," "What if," "UrbanSim," and "BUDEM" are typical types of PSSs (Wu 1998; Klosterman 1999; Waddell 2002; Long et al. 2009). According to different combinations of activities (e.g., observing, measuring, analyzing, modeling, simulating, predicting, prescribing or designing, optimizing, evaluating, managing, and negotiating) (Batty 2007), PSSs can be classified into different packages—GIS; land use transportation models (LUTMs); multicriteria analysis (MCA); plan-generation techniques such as What if? TM, CAD, and 3D GIS; and public participation/multimedia community-visioning methods (Shiffer 2001). In a sense, PSSs can be regarded as use-driven approaches to large-scale urban modeling and planning support and are thus distinguished from theory-driven methods (Geertman and Stillwell 2009).

However, PSSs have encountered bottlenecks in supporting planning and design for various reasons, including limited interest from planners, difficulties with understanding systems, and their constrained functions (Liu et al. 2014). First, barriers related to resistance to change and working habits that have been in place for years have allowed few planners to apply PSS in practice (Timmermans 2008; Vonk et al. 2005). Furthermore, consideration to the specific demands of planners and to characteristics of the PSS planning process is insufficient (Geertman 2006). Some scholars such as Van Kouwen et al. (2009) even argue that "PSSs do not bridge the gap between knowledge and policy making, but are rather part of the problem."

2.1.2 Geo-design as a Design and Planning Tool

With the evolution of Geographic Information Systems (GIS) in environment design, geo-design has also become a hot topic in academia, design institutes, and geospatial industries. Generally, any design activities informed by geographic knowledge, experience, information, and data could be called geo-design (Li and Milburn 2016). According to Li and Milburn (2016), geo-design in landscape architecture has been involved in four main eras. The first one is the analogue era (mid-nineteenth century to mid-twentieth century), which was characterized by the use of analogue media and techniques for data storage and information representation for scientific investigation and rational decision-making. The second era ran from 1950 to the mid-1970s. Driven by decades of the introduction of scientific knowledge, usage of survey data, and the initiation of analytical approaches, the classic "survey-analysis-design" process became standard practice and a central design approach (Sasaki 2002; Swaffield 2002). With the rapid development of electronic engineering and computer science, environmental data became available, resulting in the third era of geo-design called the small data era. In this era, GIS-based analysis developed rapidly and became widely used for advanced research (White and Mayo 2004), regional design, planning, and policy making (Hanna 1999; Lyle 1985). From 2000 to the present, revolutions in information technologies and spatial data have formed a lens for fine-scale geo-design practice. This era can be called the big data era, in which the creation of new definitions, principles, theories, applications, and organizations has continually emerged.

According to the definition of geo-design, the whole framework related to design activities in geographic space is a reflection of its function (Miller 2012). Some scholars have defined the function more strictly and focused on alternative design evaluation and impact assessment (Dangermond 2009; Ervin 2012; McElvaney 2012). Recently, Steinitz (2012) revised his landscape framework to provide a theoretical foundation and structure for geo-design. In his view, "geo-design applies systems thinking to the creation of proposals for change and impact simulations" (Canfield and Steinitz 2014) and can help one "understand the study area," "specify methods," and "perform studies" (Steinitz 2012). The core tenet of geo-design is spatial thinking, which involves understanding, defining, and analyzing the locations, distances, directions, shapes, scales, patterns, and trends of features and processes observed in living environments (Kastens and Ishikawa 2006) in the context of geographic information science (GIScience). In environmental design, geo-design is regarded as a methodology which facilitates the generation and impact assessment of design proposals with geospatial information and technologies. In the field of planning practice, geospatial analysis and modeling generated from geo-design serve as a planning support tool in searching for solutions of better urban form by ascertaining the patterns of activities in urban space (Neutens et al. 2010; Yuan et al. 2012; Long and Shen 2015a, b). From the perspective of planning support, geo-design can be regarded as part of a PSS. However, compared to the PSS, geo-design is a GIS-based analysis tool for capturing, storing, manipulating, analyzing, and displaying and is applicable to many different spatially related problems. Even though in many cases a PSS also contains GIS tools, it is involved in undertaking specific planning tasks.

2.1.3 New Opportunities for Integrating Big Data into Urban Planning and Design

With the advent of the fourth generation of the industrial revolution, artificial intelligence, virtual reality, augmented reality, the Internet of Things (IoTs), and various other kinds of intelligent technologies are now constantly reshaping housing, work, transportation, and recreation. Simultaneously, the information and communication technology (ICT) boom has created both "big data" through, for instance, mobile phone signaling and public transportation smart card records, and "open data" through, for instance, commercial and government websites, together giving rise to a "new data environment" (see Appendix 1 for more information) that has allowed geo-design users to take advantage of new methodologies and to transition from PSSs to data-driven planning and design.

There are three reasons why a new data-driven methodology should be proposed. First, as we described in Chap. 1, our cities are in transition. To meet this new wave of information technology, there is a concern that much more powerful theories and methods are needed to generate a requisite understanding of cities (Batty 2013).

Models and methods relying on traditional PSS framework will face challenges. Second, with the boom of new data environments, there are many types of urban data, which serve as important sources for planners in identifying planning issues and solutions in urban areas using geospatial analysis technologies (Long and Shen 2015a, b). Although geo-design is also starting to use big data for analysis, it pays more attention to the attributes of physical space and less attention to the social attributes of the city and especially activities in the virtual environment. Finally, fine-scale data provide us with a new perspective on understanding the city at the human scale. Compared to PSSs and traditional geo-design, microscale urban planning and design require the use of a series of new methods and tools.

Since 2005 (mostly since 2010), labs, departments, and schools have increasingly pursued deeply quantitative and computational approaches to understanding and creating cities. The MIT Media Lab, MIT Senseable City Lab, and ETH Future City Lab, to name but a few, are presenting data and design driven research. Similar initiatives are also underway in China (see Appendix 2 for more information). The use of new data to identify new urban life and urban physical environments is also occurring at an increasing rate. For instance, bike lanes are planned based on the trajectories of share-bikes (Bao et al. 2017) and intelligent transportation systems of the future can be improved through visual analysis (Andrienko et al. 2017).

Against this background, it was previously recognized by Long and Shen (2015a, b) that the data themselves are not platforms or software but reflect the physical and social environment, which can in turn reflect the future space and life of our cities. To better describe this data transformation in planning and design, the authors jointly proposed a new methodology termed Data Augmented Design (DAD) in 2015 (Long and Shen 2015a, b) to highlight the use of data in design. Since then, in China many scholars have conducted research in response to the concept of DAD. This paper will discuss DAD by offering a definition and introducing the specific processes, features, and tools used to realize the scope of future-oriented design. Following from this, three typical applications to DAD are presented with several practice cases. Then, the progress of DAD is reviewed with regard to its research network and annual conference, the DAD manual, courses and workshops, and feedback from academics and practitioners. A concluding section outlines main points related to DAD and discusses its potential applications in smart cities.

2.2 Data Augmented Design (DAD)

2.2.1 The Definition of DAD

Empowered by the emerging big and open urban data together with quantitative spatial analysis, statistical approaches, and cutting-edge techniques, Data Augmented Design (DAD) provides a supporting platform for the whole planning and design process, including field investigation, existing condition analysis, future forecasting, scheme design, and operation evaluation and feedback. The application of DAD in planning and design practice is expected to improve the science of planning and design and to inspire the creativity of planners and designers (Long and Shen 2015a, b). Based on an understanding of the supporting tools for planning and design, the proposed DAD system belongs to a new planning and design support format following CAD (Computer Aided Design), GISs (Geographical Information Systems), DSSs (Decision Support Systems), and PSSs (Planning Support Systems) (Table 2.1). It should be understood that DAD is not equivalent to quantitative analysis, CAD, and geo-design. As a new planning and design methodology, DAD emphasizes a future-oriented method of design. DAD focuses on applying various data to technical methods and obtaining experience from designers to quickly generate and evaluate schemes, whereas CAD focuses on providing planners with a mapping environment to improve the efficiency of generating planning and design results. Compared to geo-design, DAD concentrates more on people and their activities. In contrast to the "nonlinearity" of parametric design, DAD also does not

Table 2.1 Comparison of DAD to other planning and design support formats

Concepts	Core function	Period	Driving force	Process	Scale
ES (expert system)	A process based on knowledge and expert experience for finding solutions to problems	Long-term	Experience- and knowledge-driven	Classification, diagnosis, monitoring, design, scheduling, and planning for specialized endeavors	Whole scale
CAD (computer aided design)	Planning and design support software tools	Short-term	Data-driven	Design generation	Whole scale
GIS (geographic information system)	Planning and design support software tools	Short-term	Data-driven	Existing condition analysis, design generation, and visualization	Whole scale
DSS (decision support system)	A collection of tools for the decision-making process	Short-term	Model-driven	Decision-making	Macroscale
SDSS (spatial decision support system)	A collection of tools for the spatial decision-making process	Short-term	Model-driven	Decision-making	Macroscale
PSS (planning support system)	A collection of tools and a framework for the planning process	Long-term	Model-driven	Whole process of planning	Macroscale
DAD (data augmented design)	A collection of tools and a framework for the planning and design process	Long-term	Data-driven	Whole process of planning and design	Mesoscale and microscale

advocate the use of mathematical analysis to completely replace design thinking, but instead provides quantitative methodologies and reliable evidence for design creation with solid quantitative analysis. Although DAD is similar to a PSS in terms of the whole process supporting urban planning, there are still some differences. First, DAD is a data-driven framework and thus diverges from model-driven PSSs. Second, DAD focuses on fine-scale urban planning and design while a PSS operates in the context of macroscale urban planning. Third, DAD fully embraces cutting-edge technology in planning and design and studies the impact of new technologies on urban space and urban life.

2.2.2 Process of DAD

DAD, as a new quantitative planning and design methodology, can support each phase in the process of urban planning and design by employing modeling toolsets to extract, analyze, and predict on the basis of various data sources, and eventually, it can also increase the rationality, creativity, and resilience of planning in a new data environment. The typical application of DAD in supporting planning and design can be divided into five steps (Fig. 2.1). First, using a quantitative analysis based on the DAD framework in an existing condition analysis can inspire the extraction of design elements and the generation of concepts. Data with large coverage and fine spatial granularity can integrate different spatial factors and effects onto the same scale, overcoming difficulties with traditional planning design in matching and connecting across different scales. Meanwhile, urban data analysis methods and models are used to extract the most appropriate urban design elements using the requirements of planning regulations and master planning as control factors. This rational analysis method helps one avoid the limitations of research dimensions and personal knowledge and experience. Second, the introduction of DAD augments the optimization of planning and design via a real-time process of

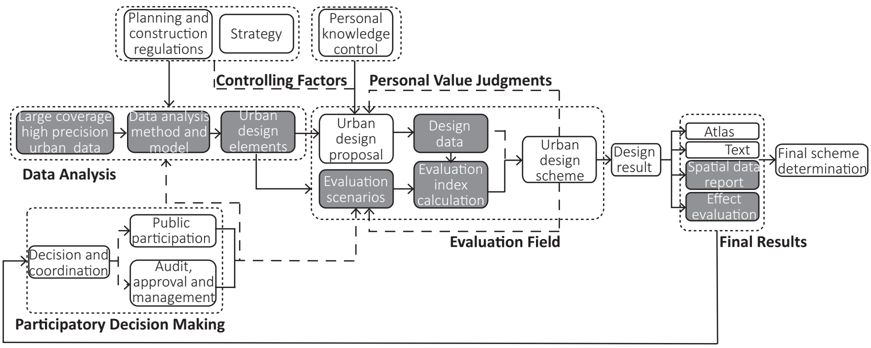

Fig. 2.1 The specific planning and design support format of DAD (Long and Shen 2015a, b) (revised by the authors)

simulation and evaluation. Third, the quantitative results of DAD can support the output expressions of planning and design. Personal judgment serves as a final filter before generating the design scheme. Then, a report of spatial data and its visualization will help reduce communication costs while ensuring the effectiveness and the implementation of participatory decision-making. Finally, the use of increasingly diverse and sophisticated urban data will lead to a more transparent urban management atmosphere and especially in aspects related to public participation, planning, and management. After these processes are complete, the design scheme is constantly optimized, thus eventually meeting scientific, feasibility, timeliness, and aesthetic requirements.

Within the framework of DAD, the interpretation of complex urban orders and their sustainability can be considered as decision-making process in which different phases are included and the most appropriate and effective spatial intervention plan is generated and proposed (Shen and Long, 2015). Figure 2.2 shows the process of connecting and implementing different spatial designs and their sustainability contributions within a dynamic, quantitative framework of urban sustainability using the DAD system. From this perspective, the DAD research framework is a specific, future-oriented epistemology system, which conducts archaeological studies on the contemporary urban situation. Such a framework not only contributes to rational planning proposals but is also helpful for understanding the sustainable functionality that underlies planned and unplanned orders.

2.2.3 *Features of DAD*

The data used in DAD are not limited to big data but also include open and traditional data. These various sources and types of data interact with each other to react and support the application of quantitative analysis in urban planning and design. Specifically, the principal features of DAD are as follows. (1) Applicable: directly responding to planning and design practice. (2) Multidimensional: a model that combines spatial attributes with socioeconomic data. (3) People-centered: studying

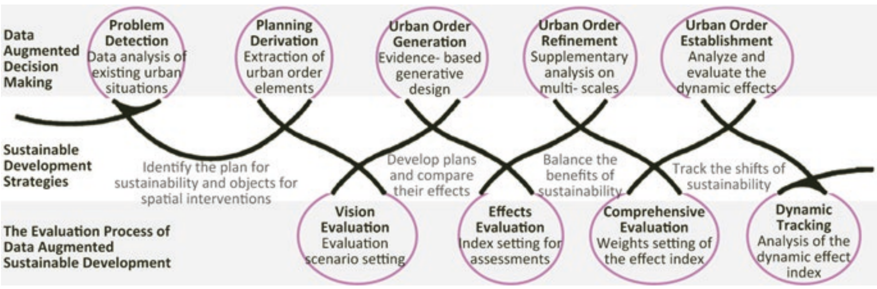

Fig. 2.2 Decision-making/reasoning process of urban planning and design towards sustainability (Shen and Long 2015) (revised by the authors)

people's activities through social networks, POIs (points of interest), mobile phone data, etc. (4) Perceptible: corresponding to the “spatial spirit” of the design with the help of new data and methods. (5) Fine-scale: emphasizing an accurate understanding of the context of the given environment and people, analyzing existing laws, and establishing different combinations of models to provide support for special planning and design. (6) Adaptable: focusing on a quantitative understanding of the relationship between people’s activities and the environment to create better ones. (7) Applying a binary world: combining the virtual world with the real world. (8) Integration: integrating multisource data and encouraging public participation. (9) Using multiple tools: reflecting design methods in a series of tools. (10) Effect-based: aiming at better social, economic, and ecological benefits of design. (11) Traceable and assessable: continuously evaluating and cycling through the design process until the best results are available.

2.2.4 Commonly Used Methods and Tools of DAD

There is a tendency for methods and tools used in DAD to be increasingly more closely linked to new data and new technologies. The main methods of DAD include the following (Table 2.2): (1) applying spatial abstraction models for identifying and abstracting design and analysis of spatial units such as spatial syntax, the grid division method, and node analysis; (2) using spatial analysis and statistics to identify statistical characteristics of space such as spatial statistical methods, density analysis methods, and interpolation analysis methods; (3) using data mining and visualization tools such as machine learning and spatial visualization; (4) applying natural language processing to discover information in social network data such as stop words, word clouds, and semantic analysis; (5) employing urban development

Table 2.2 Commonly used methods and tools of DAD and their key functions

Commonly used methods and tools	Key functions	Samples
Spatial abstraction models	Identify and extract spatial units for design and analysis	Spatial syntax, the grid division method, and node analysis
Spatial analysis and statistics	Identify statistical characteristics of space	Spatial statistical methods, density analysis methods, and interpolation analysis methods
Data mining and visualization	Mine and visualize data information	Machine learning and spatial visualization
Natural language processing	Discover information included in social network data	Stop words, word clouds, and semantic analysis
Urban development models	Predict urban development boundaries and short- and long-term effects of planning design	Cellular automata, multiagent models, and urban procedural modeling
Parametric design tools	Generate design schemes automatically	Grasshopper and city engine

models to predict urban development boundaries and short- and long-term effects of planning design such as cellular automata, multiagent models, and urban procedural modeling; and (6) adopting parametric design tools to generate design schemes automatically such as Grasshopper and City Engine.

2.3 Three Typical Applications of DAD

The design of DAD is based on the in-depth observation and understanding of a current city including its physical environment and individuals' activities. According to different types of design, we can divide our applications into three categories (Fig. 2.3). For redevelopment-oriented planning and design, we emphasize better understanding elements by using multisource data. For expansion-oriented planning and design, we encourage learning from excellent city cases by comparing their quantified attributes on the same scale. For future cities, we observe transitions in current cities influenced by advanced technologies and fully embrace cutting-edge technologies to imagine future urban life and create future urban forms.

2.3.1 Understanding the Elements of a Site to Better Design Sites

DAD can be applied to redevelopment-oriented planning and design, which helps identify problems via an existing condition analysis based on multidimensional data, and to quantitatively evaluate the implementation of designs after reconstruction (Cao and Long 2017). First, under the guidance of the TSP model (Long and Shen

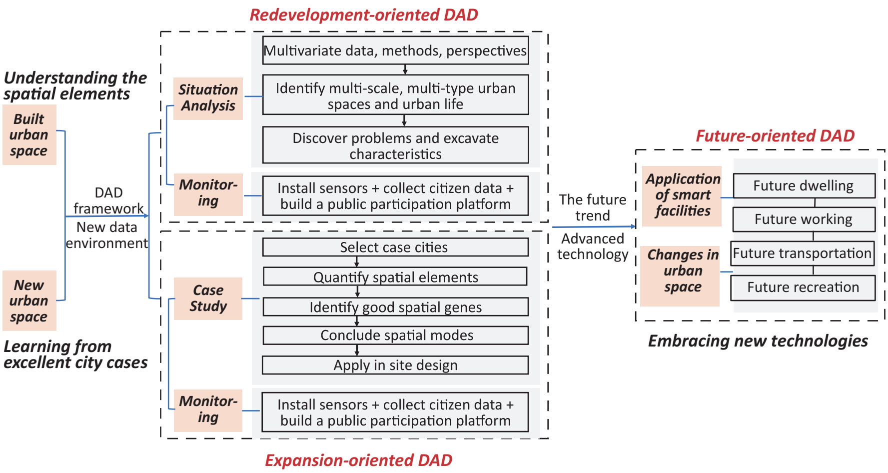

Fig. 2.3 Three typical applications of DAD for different design types

2016), the framework supports an understanding of physical and social space via analysis of upper planning, physical environmental elements, social networks, and economic performance. This way, existing problems in different dimensions such as functional positioning and service facilities distribution are recognized. This process prioritizes the “people-centered” approach by dealing with existing problems and responding to the demands of citizens. Based on this framework, two teams using DAD in both the 2016 and 2018 Shanghai Urban Design Challenges have been supervised and received very good outcomes. In these two works, DAD as a methodology for urban design provided different means of analyzing big and open data in different dimensions (for an example, see Fig. 2.4). In redevelopment-oriented planning and design, shrinking cities are also an important issue. Although some international strategies have been designed to cope with the shrinkage of cities, few of such designs have been developed in China. In 2019, the China Shrinking City Research Network launched a workshop on shrinking cities in the city of Hegang, China. Another team guided by the DAD framework also achieved good outcomes.

2.3.2 Learning from Other Cases to Better Design Sites

DAD can also be applied to the planning and design of urban expansion, which helps extract spatial indexes from existing cases to form a classified “gene pool” for quantification and a reference index system for new designs (Gan and Long 2018). The specific framework is constructed over three steps (Fig. 2.5): first, there is an analysis of the built environment of the selected case cities based on the new data environment and DAD method where the extracted and quantized index from the spatial dimension is added to each gene pool; next, each suitable gene pool is used for planning and is adjusted according to its specific conditions; finally, a quantitative evaluation is made for the postconstruction city space, including a comprehensive comparison of the status of the planned city and the corresponding index of the case city. Based on this method, DAD was successfully applied in the Tongzhou Sub-Center of Beijing and Xiong’an New District projects, proving the applicability of DAD concepts to Chinese planning and design.

2.3.3 Embracing Advanced Technologies and Transitioning of Cities into Better Designed Sites

The third type of DAD application is future oriented. As we introduced in Chap. 1, we live in a time of very rapid development and change that is driven by various forms of science and technology, which have the potential to change the way we live, work, spend free time, and travel. Only by embracing the most advanced technologies and transitions in cities can a better future be created. First, we should conform to the reconstruction of urban space by science and technology and imagine a future

Fig. 2.4 Walkability evaluation derived from the 2016 Shanghai urban design challenges

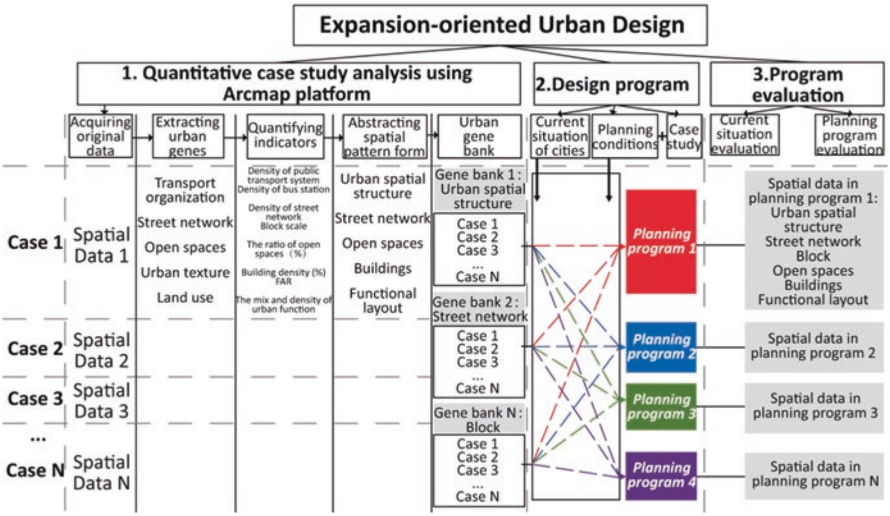

Fig. 2.5 The quantitative case study framework

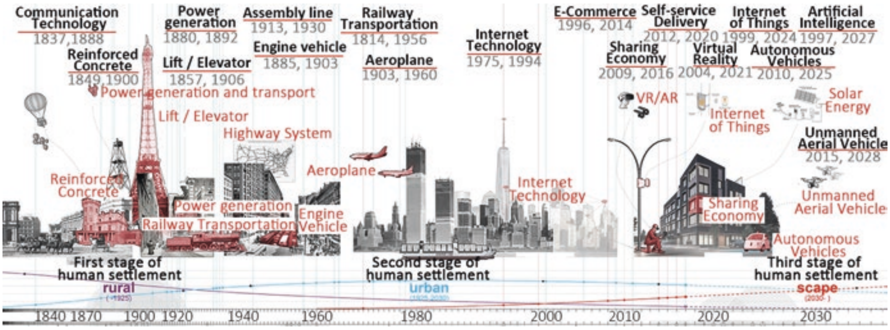

Fig. 2.6 The transformation of human settlements through emerging technologies

urban form under the influence of new technologies such as autonomous vehicles, smart logistics, VR, UAVs, artificial intelligence, and sharing technologies (Fig. 2.6). This concept is reflected in the work *The Next Form of Human Settlement* submitted to the Yilong Futuristic City International Design Competition. This work focuses on living spaces of the city and proposes an assumption of future living form. This scenario is illustrated in Chap. 9. Then, we should also fully integrate certain existing technologies into our design. In combining design with technology, our design is not limited to physical space but is also expanded into virtual space. Through the development of Huangguan Island, we connect design with nature and technology and augment nature with science and technology, which is interpreted in Chap. 10.

These practice cases reflect the applicability of redevelopment- and expansion-oriented urban planning and design using DAD and its future-oriented attributes and form. This book will also focus on the design practices of these three types of application methods and specifically introduce the application of DAD methodologies across different design situations to provide new ideas and methodological support for design.

2.4 Recent Progress and Achievements

The DAD methodology has attracted widespread attention from academia and industry since it was first proposed and has achieved some progress so far, which is mainly reflected in the following aspects. The first concerns the formation of a research network based on DAD. At the annual academic symposium on DAD, endless studies are presented on the combination of data and design from academics and industry, promoting the development of data-driven design research. Second, a DAD guideline guided by methodology further refines the DAD method and its research content. Third, a trend of combining data with design has also been applied and promoted in college courses. The first author of this book launched a course named *Big Data and Urban Planning* at Tsinghua University, which attracted the attention of academics and achieved good outcomes. After a series of efforts, we received ample feedback from academia and industry. Therefore, we also hope to summarize the staged achievements of DAD in this chapter as an exploratory reference for planning and design methods in the new era.

2.4.1 Research Network and Annual Conferences

The DAD research network, established in 2015 as a community for DAD and led principally by a team from Tsinghua University, has been dedicated to the research and application of DAD. The DAD symposium, an annual conference for the DAD research network, was launched to facilitate the dissemination of up-to-date DAD research and applications from members of the research network. Five annual conferences have been held (Table 2.3), in which a large number of research institutions and individuals have participated, sharing and discussing pioneering research and design practices. The organization of these conferences can be regarded as a sign of broad acceptance of DAD in China. Readers seeking more detailed and slightly more technical information are referred to the BCL website, which lists the program of the third DAD symposium (https://www.beijingcitylab.com/projects-1/17-data-augmented-design/symposiums/).

2.4.2 Data Augmented Design Manual

Inspired by the DAD methodology proposed by Long and Shen (2015a, b), Mao et al. (2016) developed a DAD manual for better supporting urban planning and design practices in China. The manual (Fig. 2.7) was put forward to support urban renewal. In this manual, for different levels of planning, tools, methods, indicators, and other aspects of planning and design were proposed with respect to the analysis

Table 2.3 Information on the five previous annual conferences on DAD

Order	Time	Place	Themes	Number of Reports
1	2015.12.05	Beijing Jiaotong University	Analysis and design in the data age	39
2	2016.12.10	Tsinghua University	Data augmented design	22
3	2017.12.23	South East University	New ideas and methods for DAD; application of multisource big data to urban planning and design; DAD at the human scale	11
4	2018.12.27	Tsinghua University	Data, design, and the city	13
5	2019.12.23	China Architecture Design & Research Group	Data augmented design	9

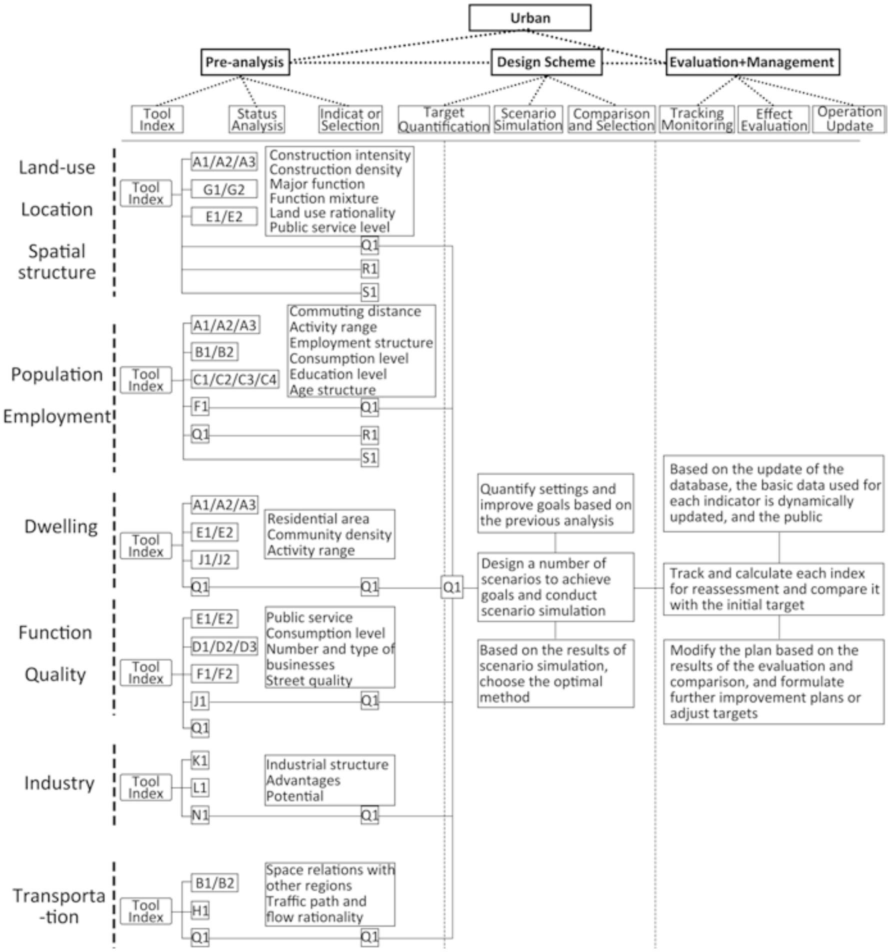

Fig. 2.7 The data augmented design manual for supporting urban renewal projects (Mao et al. 2016)

of the current status, program design, and evaluation and operation phases, rendering this a holistic solution for planning and design in the new data environment. Specifically, based on multisource data, the manual selects various elements (e.g., land use, location, spatial structure, population, employment, residence, functional quality, industry, transportation, etc.) as objects for analysis and research to guide users through the planning and design process and through the three phases of analysis, design, and evaluation.

2.4.3 Education and Workshop

Educating urban planning graduate and undergraduate students, most of whom will become urban planners, with knowledge of DAD is important in advancing its further application. DAD has only been introduced into several courses under the Department of Urban Planning at Tsinghua University (Long 2016). Such courses are titled *Big Data and Urban Planning*, *Structural Urban Design*, *Urban and Rural Comprehensive Surveying*, *An Introduction to Urban Modeling*, and *A New Science of Cities*. The spirit of DAD in these courses has been informational, allowing students to focus more on data analysis and quantitative studies in design. The courses can be divided into theoretical and practical courses.

Theoretical Courses Expand Students' Perspectives and Promote Acceptance of New Data and Cutting-Edge Technologies

Theoretical courses, such as *An Introduction to Urban Modeling* and *A New Science of Cities*, as cross-disciplinary courses fully combine new data and cutting-edge technologies in various professional fields. They provide important opportunities for better understanding the urban system and its development rules and outline important theories and technical support for urban research, planning, and management. *An Introduction to Urban Modeling* illustrates both recent progress in urban modeling and the foundations of the Chinese urban system, providing students with a basis for applying urban modeling such as analytical methods and data visualization tools as well as various mainstream urban models (e.g., spatial interaction, cellular automata, multiagent systems, system dynamics, network analysis, and artificial intelligence models). *A New Science of Cities* combines the recent progress of the new science of cities with its urban applications, including the contents of IoTs and citizen sensors, virtual and augmented reality, intelligent construction, artificial intelligence, computer vision, advanced urban modeling, and smart cities. It aims to enhance students' knowledge bases and to expand their perspectives on new data and cutting-edge technologies, the most important component of DAD. Such courses constitute early attempts to deliver theoretical courses related to urban science and urban modeling in China.

Practical Courses Encourage Students to Apply the DAD Framework and Philosophy in Design Studios and Workshops

Practical courses, including *Big Data and Urban Planning*, *Structural Urban Design,* and *Urban and Rural Comprehensive Survey*, serve as good opportunities for students to apply DAD to interdisciplinary urban studies and design practices. In these courses, students are encouraged to combine quantitative analysis with existing condition surveys and analysis for a more comprehensive study of sites. GIS tools, the

GeoHey online visualization (www.geohey.com) platform, and new approaches to data mining and analysis are introduced to support the generation of design schemes, providing a stronger application of DAD to the design process. The course titled *Big Data and Urban Planning* also encourages the use of the online MOOC platform, which combines both recent progress in big data analysis and its applications to urban planning and design. Content focuses on big data acquisition, analysis, visualization, and applications of planning tools from urban modeling methods to typical models as well as the emerging trends and potential revolution of big data in urban planning. Readers seeking more detailed information on this course are referred to https://courses.edx.org/courses/course-v1:TsinghuaX+70000662+1T2020/course/.

2.4.4 Feedback from Academics and Practitioners

With progress in DAD, the approach has received more attention from researchers involved in planning and design. (1) It has led to several special issues on the topic published in leading Chinese academic journals such as *Urban Planning International*, *Planners* and *Ideal Space*. (2) The lead researcher behind DAD has been invited by different planning and design institutes such as the Chengdu Planning and Design Institute, Qingdao Urban Planning and Design Institute, Shandong Urban and Rural Planning and Design Institute to report on DAD, and the journal *Chengdu Urban and Rural Plan* published a special issue on these reports. (3) The Human-scale Urban Form theory proposed by Long and Shen (2016) based on DAD has been well recognized by multiple experts, including the editor in chief of the journal *Landscape and Urban Planning*, in which he writes, "This is my favourite proposal, in the sense that the topic area is an exciting emerging area… I believe this to be a highly original and important theme for the special issue 'Measuring Human-scale Urban Form and Its Performance' in a rapidly developing field of science with increasing potential for applications in practice." This theory and its relationship to DAD will be introduced in next chapter.

2.5 Concluding Remarks and Discussion

2.5.1 Concluding Remarks

In reviewing the foundations and prerequisites of data and design, this chapter highlights tendencies of data-driven research and design, which have led to the introduction of a new planning and design support system termed Data Augmented Design (DAD) first proposed in 2015. In drawing on all kinds of data, including big, open, and conventional data, and embracing cutting-edge technologies, DAD can be regarded as a future-oriented design framework in terms of its focus on multidata, multimethod, multistage, and multiscale approaches and use of a new planning and design support format following CAD, DSSs, GIS, and PSSs. To better describe DAD, this chapter demonstrates the applicability of DAD within contemporary urban planning by introducing its three types of applications. Its progress in terms of the DAD research network and annual conference, the DAD manual, courses, and workshops are also illustrated. Planners, officers, and students as well as citizens can benefit from the research and design practices of DAD.

2.5.2 *Potential Applications*

Potential applications of DAD fall under two categories. First, as a new planning and design methodology, DAD has great potential to support multiscale urban planning and design practices, including redevelopment- and expansion-oriented urban planning and design. The other category of applications is future-oriented, under which DAD is most recognized for being committed to understanding new cities and combining new technologies to change new spaces, which can be used in the construction of smart cities. The data generated by advanced technologies in smart cities could provide support for DAD research, and DAD-based designs will combine the development of smart cities, comprehension of future urban forms, and the promotion of smart infrastructure construction and sensor application (Fig. 2.8).

2.5.3 *Future Trends*

As mentioned in Chap. 1, urban life and urban space are in transition as a result of technological developments. "Design" in DAD should also respond to and reflect this trend. Traditional design pays more attention to means of spatial intervention. However, with the application of sensors and the development of Internet of Things

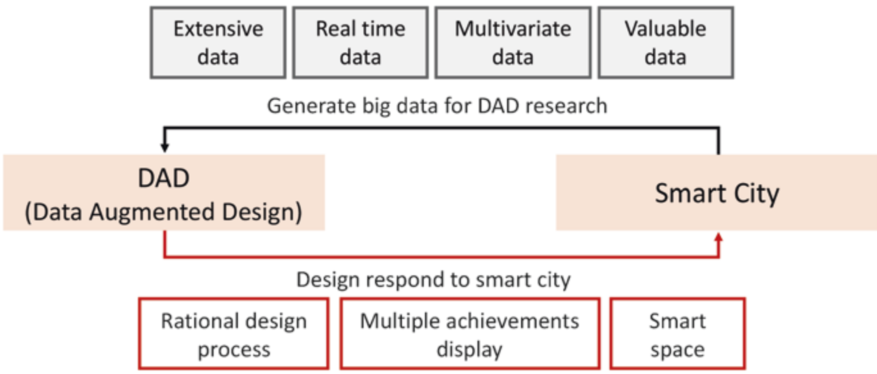

Fig. 2.8 Relationships between DAD and smart cities

technology, future design will also embrace advanced technologies. Digital innovation will play an important role in design. Spatial design elements, including spatial interfaces of different functions and all kinds of urban furniture will be digitized, rendering space more intelligent, convenient, and flexible. In addition, digital means that do not rely on spatial elements such as mobile phone applications, AR (Augmented Reality), and VR (Virtual reality) will also change the use of space. The combination of Spatial Intervention and Digital Innovation (SIDI) is at the root of the future development of DAD and will guide the spatial projection of smart cities.

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Chapter 3
Human-scale Urban Form and Its Application in DAD

Abstract The human-centered perspective has been widely mentioned in the world. Accompanying with the raising call for human-centered consideration in urban design, a series of new data environment and new analytical methods bring new potentials for achieving this goal. For instance, the new data environment consisting of big data and open data could provide a foundation for in-depth studies of human-scale urban form and its related performances. New techniques and methods, e.g., Lidar imaging, virtual reality, eye-tracking, deep learning, big data mining and visualization, provide emerging insightful analytical approaches. Therefore, this chapter interprets the conceptual framework of human-scale urban form, which is the theoretic basis for DAD. Following this route, this chapter firstly reviews existing studies related to the concept. Three essential issues of human-scale urban form, i.e., measurements, performances, and urban design interventions, are then discussed to guide future researches. After that, several initial studies are illustrated as empirical examples. It could promote the transition towards more scientific urban design paradigms, and finally contribute to better urban spaces.

Keywords New data environment · Human-scale · Urban form · Urban design · Social performance

3.1 Human-Scale Urban Form

With rapid automobile-oriented urban development, there has been growing research interest in people-centered urban spaces, which encourage outdoor activities and social interactions (Xu 2019). Urban design, especially human-based urban space design, has become one of the key points. The increasing interest in urban quality, vitality, and design requires a deeper understanding of human-scale urban form.

Throughout the history of urban planning and design, most existing theories have been related to human-scale urban form. According to Long and Ye (2019), human-

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https://doi.org/10.1007/978-3-030-49618-0_3

scale urban form means a fine scale characterized by the human body and its surroundings, i.e., a scale that is directly visible, touchable, and appreciable in a person's daily life. However, in the past, limited data sources and insufficient analysis tools constrained the measurement and evaluation of urban form. Recently, the new data environment and advanced technologies have made possible the objective study of the interactions between people and their surrounding environment. Specifically, by integrating multisource urban data and geospatial analyses, we can gain insights into how people use urban spaces, how they feel about them, and how space performs in various kinds of situations (Zhang et al. 2019).

Human-scale urban form is closely related to human attributes, which can be seen and felt by human beings. It is also a necessary supplement to the current grid, block, and land scale for urban form. Streets, buildings, and attributes of the surrounding physical environment (sound, temperature, light, etc.) are the components of human-scale urban form. In the context of the new data environment, technologies, and methods constantly emerging, human-scale urban form has considerable development potential and is expected to become an important direction of urban research in the future. In 2019, a special issue of Landscape and Urban Planning (LAND) titled "*Measuring human-scale urban form and its performance*"[1] represented a collection of approaches to analyzing, describing, and understanding the physical fabric of human-scale urban form and its corresponding socioeconomic performance (Long and Ye 2019). More extensive and in-depth studies in this avenue are expected, given the ubiquitous Internet of Things and the popularity of wearable devices, which are promising data sources for research on human-scale urban form. In view of the in-depth study of humans and their surrounding built environment, human-scale urban form is helpful for fine-scale design under the DAD framework. As a methodology of quantitative analysis, DAD can provide support for human-scale urban form.

3.2 Literature Review

3.2.1 Fine-Scale Urban Morphology Measurement

The study of human-scale urban forms such as shapes and structures and their associated performance dates back to the 1960s. Jacobs (1961) and Lefebvre (1962) were pioneers in describing the characteristics of human-scale urban form. Inspired by their insights, some qualitative research (Gehl 1987; Whyte 1980; Lynch 1981) was conducted to describe what is good urban form and how it benefits urban activities.

Following these subjective studies, a series of quantitative methods were developed to explore human-scale urban form in a more rational and objective way (Jackson 2003; Fan and Khattak 2009; Ewing and Clemente 2013). In recent decades, the rapid development of information and communication technology

[1] https://www.sciencedirect.com/journal/landscape-and-urban-planning/vol/191/suppl/C.

(ICT) has led to the rise of new urban science, offering a new infrastructure for perception, data collection, and analysis of urbanism (Townsend 2015). The new data environment represented by big data and open data and various new technologies and methods make it possible to measure urban morphological characteristics at fine scales in two directions (Liu et al. 2015; Long and Shen 2015).

First, the boom in the new data environment with detailed spatial location information provides a solid database for more comprehensive urban morphology research. Open data such as OpenStreetMap provides unprecedented large- and fine-scale data, including streets, buildings, blocks, and other elements of urban morphology, so that researchers can follow classical methods of urban morphology analysis while overcoming their shortcomings of focusing on a small scale (Ye and van 2014). In addition, big data such as street view images (SVIs) (e.g., Google Street View) has provided new possibilities for measuring human-scale urban form; SVIs have been used for green visibility analysis of street views (Li et al. 2015; Lu et al. 2018), street space quality evaluation (Naik et al. 2014; Tang and Long 2019), and many other purposes. Moreover, 3D models of buildings and streets generated by laser scanning (LiDAR) are a supplement for better depicting the physical urban form.

Second, the emergence of a series of quantitative analysis techniques has provided novel methods for measuring finer-scale urban forms. The combination of GIS technology and traditional urban morphology considerations has promoted a series of tools for quantitative urban morphology analysis, such as Spacematrix (Berghauser-Pont and Haupt 2010), space syntax (Ståhle et al. 2005), and urban network analysis (Sevtsuk and Mekonnen 2012). Such tools provide support for refined urban morphology research, unlike planning support or design support systems, which do not consider design objectives and urban form and are not fully used in the field of urban design. These newly emerging analytical tools rely on the understanding of traditional urban form and urban design, which can be effectively accepted by designers at the block scale. In addition, three-dimensional measurement techniques such as LiDAR imaging and the CityEngine platform make possible the acquisition and analysis of high-precision three-dimensional data of urban form and can meet the accuracy requirements of human-scale urban form analysis (Shiode 2000).

3.2.2 *Fine-Scale Urban Form Performance Evaluation*

The new data environment, new technologies, and new methods not only provide support for the measurement of urban form on a fine scale but also make possible the analysis of urban form performance. Big data and open data, such as mobile phone data (De et al. 2016), social network data (Shen and Karimi 2016), GPS tracking data (Bielański et al. 2018), and geotagged photos in social networks (Samany 2019), can intuitively reflect the frequency, duration, and sentiment of people in various human-scale spaces. As deep learning, machine learning and visualization technology are further applied to urban research, the related economic and social performance of urban form can be acquired and analyzed in depth (Hara et al. 2014; Ye et al. 2018). Such studies can provide a more comprehensive description of urban physical space and social space and help research on urban form performance shift from subjective empirical judgment to objective systematic analysis. In practice, the short-term and rapid analysis of urban form performance can help planners integrate it into the whole design process and make better use of the shape of urban form to promote economic and social effects.

At the same time, the development of a series of new technologies, such as virtual reality technology, eye-tracking technology, and physiological sensor technology, also provides a new direction for the analysis of urban form performance from a humanistic perspective. A cave automatic virtual reality environment and head-mounted display can provide a fully immersive and controllable virtual reality experience (Kuliga et al. 2015). Combining eye tracker and physiological sensor technology, researchers can directly analyze the behavior and feelings of various spatial morphological elements. This series of technologies can provide more detailed environmental characterization and a more accurate record of behavior and perception to help gain a deeper understanding of the human-built environment interaction.

3.3 Framework: Measurement, Performance Evaluation, and Urban Design Intervention

The study of human-scale urban form is mainly based on the human perspective and focuses on the elements of urban spatial morphology and their corresponding performance. Specifically, urban form elements including the urban public space (streets, greenery, parks, etc.) and the external façade of buildings and their economic, social, and ecological performance are objectives we measure in this study. In this chapter, the framework of human-scale urban form is divided into three parts: morphological element measurement, performance evaluation, and design intervention (Fig. 3.1).

3.3.1 Measurement

The measurement of human-scale urban form focuses on quantifying the physical and spatial elements of small cities that people frequently come into contact with in their daily life, such as street interfaces, building facades, parks, and greenery. The measurement content covers location, size, function, density, diversity, and quality, which were difficult to depict in the past. In other words, limited by the technologies and methods of the past, it was difficult to effectively measure, analyze, and manage the small-scale factors closely related to human life. These metrics can be computed using existing big data and open data and can also be applied in design interventions based on new sensors. Taking the street as an example, first, we can measure some physical space properties such as openness and enclosures based on the SegNet decoder (Kendall et al. 2015; Badrinarayanan et al. 2015) and street wall continuity and the cross-sectional proportion based on 2-dimensional GIS analysis (Harvey et al. 2017) (Fig. 3.2). Second, we can segment images and identify important elements via street view images and artificial intelligence. Elements such as buildings, poles, roads, pavements, trees, sign symbols, and fences as well as their proportion can be identified and quantified by semantic pixel-width image segmentation methods (Fig. 3.3), such as YOLO, ImageNet, SegNet, and DeepLab. With the emergence of the new data environment and new technologies, we can try to measure the visual quality of street space (vQoSS), which was difficult to measure in the past, to better understand human-scale urban form (Tang and Long 2019). Computer-assisted auditing and evaluation have become increasingly popular and can be conducted

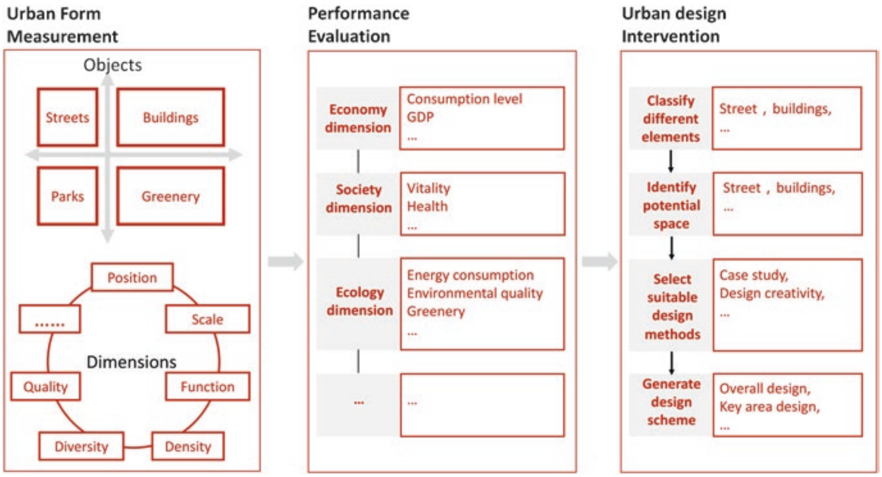

Fig. 3.1 The framework of human-scale urban form

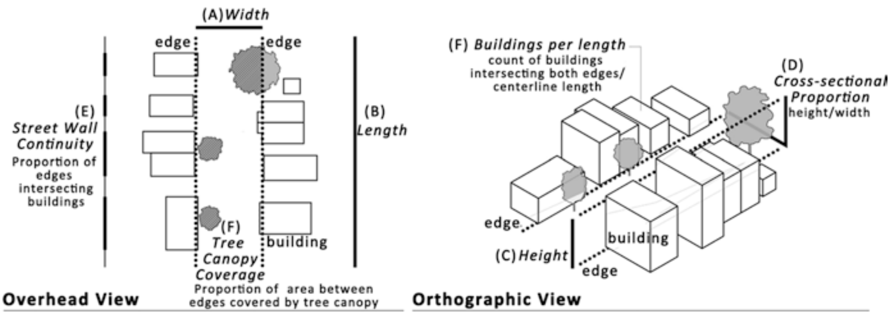

Fig. 3.2 Street landscape variable indicators (source: Harvey et al. 2017))

Fig. 3.3 A segmentation demo by SegNet (http://mi.eng.cam.ac.uk/projects/segnet/)

through an online website. In a project named Place Pulse, the MIT Media Lab is exploring how to quantitatively identify the characteristics of areas such as the extent to which they are wealthy, modern, safe, lively, active, central, adaptable, or family friendly, which were unmeasurable in the past (http://pulse.media.mit.edu). Artificial intelligence, such as machine learning, can conduct a further exploration of computer-assisted vQoSS auditing and evaluation.

3.3.2 Evaluation

The urban form measurement focuses on the spatial characteristics of cities, while the performance evaluation concentrates on the extension of urban form, which is mainly reflected in the economic, social, and ecological dimensions. Economic performance can be reflected by the consumption level and GDP (gross domestic product). Social performance is reflected by the activities and health level of people. Ecological performance refers to energy consumption, environmental quality, and green visibility. For a long time, there have been many qualitative summaries and empirical discussions on the elements of urban form and their performance. In recent years, the emergence of the new data environment and new technologies and methods has enabled us to measure urban form elements objectively and quantitatively for the first time (Ye and van 2014) and to quantitatively evaluate the performance of urban form. It has been more than 40 years since Rapoport (1977) first proposed the idea of taking the human-built environment as the core to consider urban form and design. We can perform in-depth research on the urban form and its performance at a refined scale in a scientific way, and their relationship is expected to improve existing urban theory or to develop new urban theory.

3.3.3 Urban Planning and Design Interventions

Research on the measurement method of urban form, performance evaluation, and their relationship can be used to support the whole process of planning and design. First, the measurement of spatial elements at fine scales, such as streets and buildings, helps to provide a fine basic data platform for designers that can be incorporated into the whole design process. Second, the integration of urban form measurement and performance evaluation is helpful in identifying the opportunity space and in providing suggestions for planning and design. Third, the methods used in measurement and evaluation provide potential for case study and creativity generation, accelerating the transition in the design process. Finally, the measurement of human-scale urban form and the evaluation of the performance of planning and design can also help to adjust the scheme or choose an optimum scheme from different schemes by simulating different scenes.

3.4 Case Study

This section introduces the following four cases, which cover the measurement of physical space and its quality in the context of human-scale urban form, the evaluation of social performance and research-based design. More studies related to human-scale urban form are also available in the special edition of Landscape and Urban Planning (LAND) titled "Measuring human-scale urban form and its performance" (see footnote 1).

3.4.1 Computer-Assisted Street Landscape Measurement

Streets are an important part of urban public space and a place where a large number of activities take place. Additionally, the form, proportion, and scale of buildings on both sides of the street are very important for people's perception. This case uses Beijing three-dimensional building data to measure and classify the street landscape form and ultimately to explore its impact on street vitality. Referring to Harvey et al. (2017), a method of measuring the geometric shape of street landscapes based on a GIS tool is applied. An algorithm simulating the human visual angle is used to help recognize street edges automatically. Based on the identification of street edges, 12 street landscape variables related to the geometric shape of buildings are calculated, namely the street view width, street length, the average height of buildings on both sides of streets and cross-sectional streets, the ratio of width to height, the continuity of buildings along the street, the number of buildings on both sides of the street, the standard deviation of building height on both sides of the street, the ratio of buildings penetrating into the street scene, and the curvature of the street. Then, these 12 landscape variables are input into machine learning to be clustered into different types.

Finally, the parameter representing street vitality extracted from Internet LBS data is used to analyze the impact of the three-dimensional street landscape on street vitality by comparing the results of the 12 landscape variables and street landscape types. The results showed that 13% of the streets in Beijing have no buildings on either side, 42% have buildings on one side, and 45% have buildings on both sides. The average street width of buildings is 50 m, while the average street width of buildings on one side is 27 m. After cluster analysis, the streets in Beijing mainly showed a pattern of high width, with a high number of buildings and lower building height.

3.4.2 *Quantitative Measurement of Urban Street Space Quality*

The quality of street space, lively built environments, and human-centered public space have become hot topics and crucial environmental improvement strategies for better cities. Tang and Long (2019) explored a new method of measuring the quality of street space. First, through the new data environment, they constructed a framework to measure the quality of streets, which includes two dimensions: objective element analysis and the subjective evaluation of users (Fig. 3.4). For objective element analysis, physical elements are identified (Kendall et al. 2015) and understood with the help of Bayesian SegNet technology of pixel-level semantic segmentation. Four indicators, namely the visual greenery ratio, street openness, interface enclosure, and mobility, are selected to identify the quality of streets from an objective perspective. For subjective evaluation, the scoring process of users' subjective evaluation is carried out according to Ewing and Clemente (2013), which includes enclosure, the humanization scale, permeability, cleanliness, and imagery. Subjective evaluation of the five indicators is conducted as follows: each indicator is divided

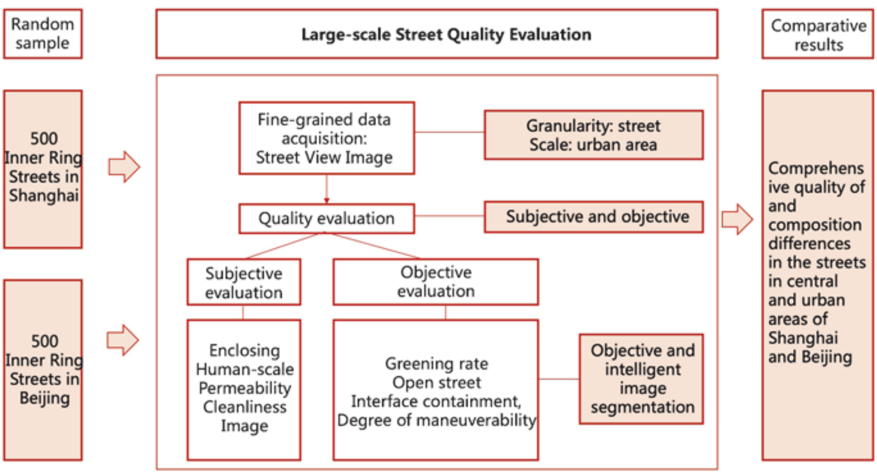

Fig. 3.4 The framework for measuring street space quality

into "low or high," and its corresponding score is 0 or 1; thus, the highest score is 5, and the lowest score is 0. Second, the scores select the streets in the central areas of Beijing and Shanghai as samples to conduct an empirical study. The results showed that the quality of street space in the central districts of mega-cities was average, the street cleanliness and the sense of spatial enclosure were good, but the permeability of the streets was poor. Additionally, the results showed that the current design had not embodied the concept of fine-scale design. There was little difference between different street spaces, which showed that they lacked identifiability and regional features. Moreover, insufficient consideration is given to the safety, convenience, comfort, and visual pleasure of walkers. Compared to Beijing, Shanghai's streets are more human oriented, more transparent, and cleaner.

3.4.3 Social Performance of Urban Form and Its Impact Factors

As mentioned above, the evaluation of urban form performance has become possible, and it helps to adjust and select design schemes. Hao et al. (2016) measured street activities in Beijing's fifth ring road and divided them into three types—'A' refers to public management and services, 'B' refers to commercial activities, and 'R' refers to dwellings. Then, they analyzed the relationship between activities and urban form with three sets of indexes and compared the impact factors of street activities in Beijing with those in Chengdu. Specifically, first, the activities of Beijing streets were analyzed from two dimensions: the external expression of street activities (density of social network activities) and their impact urban form factors (location, street texture, street type, traffic accessibility, mixed land use, built density, and own characteristics). Second, by adding spatial syntax indicators, they constructed three groups of controlled experiments, namely one considering only spatial syntax, another considering only the attributes of streets and their surrounding environment, and still another considering both. The results showed that space syntax indicators can slightly enhance the explanatory power of the impact of the factors on street activities. Finally, this research explored the planning and design strategies for street activities within the framework of data augmented design (Fig. 3.5).

3.4.4 Street Design Based on Quantitative Research

Under the DAD framework and the concept of human-scale urban form, this research studies the street design of 7322 districts in Chengdu and measured the function and vitality (density of activities) of urban streets within 5.7 km^2 of the districts. According to the function of streets, this research divided streets into three

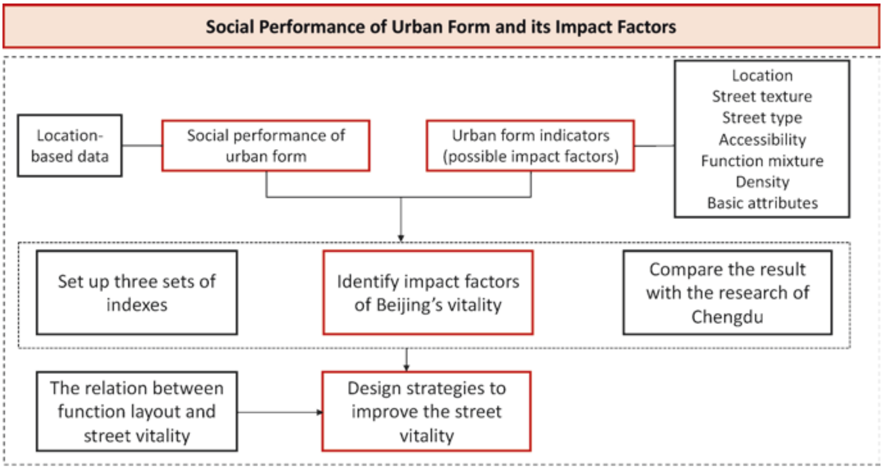

Fig. 3.5 The framework of measuring the social performance of urban form in Beijing

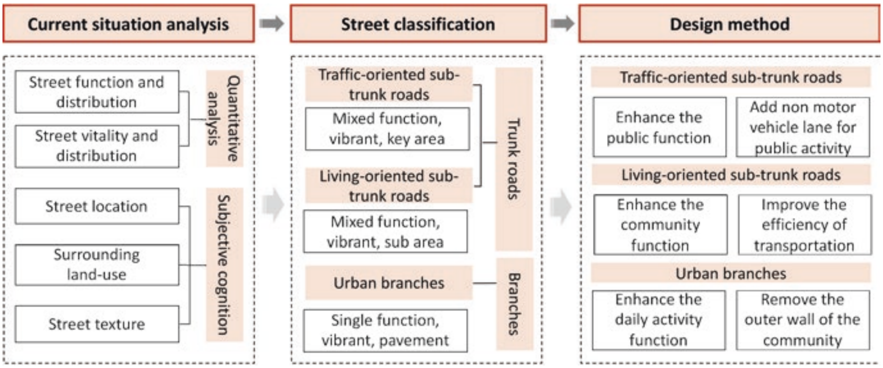

Fig. 3.6 The framework of street renewal design in Chengdu

types and formulated corresponding strategies for different types of streets (Fig. 3.6). First, this research identified the main function (traffic, living, etc.) of each street using POI (point of interest) data collected from an online map. Then, social network system (SNS) data such as DianPing and Weibo check-in data were used to reveal the vitality pattern and its high score in different situations, such as day and night. The current situation of the road network was also analyzed by objective and quantitative methods using road network data. On this basis, streets in the area were divided into three types: traffic-oriented subtrunk roads, living-oriented subtrunk roads, and urban branches. Finally, some design strategies were proposed to optimize these three types of streets. Thus, current streets will be promoted, and the street pedestrian environment will be improved, reaching the goal of human-scale streets.

3.5 Discussion of DAD and Human-Scale Urban Form

DAD is a methodology that emphasizes fine-scale urban research and design and can provide novel methods and tools for human-scale urban form research. In turn, human-scale urban form can help us better respond to the needs of rational urban design, which is also the core concept of DAD. Specifically, on the one hand, the combination of the new data environment and new analytical methods in the DAD framework facilitates a sophisticated approach to research on human-scale urban form through the process of morphological element measurement, performance evaluation, and design intervention. On the other hand, human-scale urban design is the core of DAD, which is based the human-scale urban form. Research on human-scale urban form is helpful for DAD with respect to objective understanding, problem diagnosis, trend judgment, and even spatial intervention on a human scale, and ultimately, it is helpful for achieving the goal of enhancing the process of design and improving the quality of urban space.

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Part II
Understanding the Elements of a Site to Better Design Sites

Chapter 4
Data Adaptive Urban Design: A Case Study of Shanghai Hengfu Historical District

Abstract Data Augmented Design (DAD) can be applied to the redevelopment-oriented urban design, which helps find problems via an existing condition analysis based on multidimensional data, and quantitatively evaluate the implementation of designs after reconstruction. Based on this framework, a data adaptive urban design solution for redevelopment-oriented urban space is proposed in this chapter. It integrates space measurement and feedback into the process of urban design, which will convert the long-term design evaluation into short-term spatial intervention. Through establishing ICT infrastructures on a site, the feedback from precise and customized big data can be applied to promote the interaction between urban space and social activities. This chapter displays a series of quantitative methods including the workflow and tools to analyze opportunities and challenges of the design site. To better describe the framework, we take the design in Shanghai Hengfu historical district as a case study to depict the application of DAD in redevelopment-oriented urban design.

Keywords New data environment · Data adaptive · Urban design · Historical district · Slow traffic system

4.1 Introduction

Industrialization and informalization have shaped urban regional patterns, built environments, and socioeconomic structures throughout history, further shifting the paradigm of the understanding and designing of cities. Urban design theories have undergone several stages of development since the eighteenth century (Table 4.1), from the layout of groups of buildings to systematic configurations of urban form and functions with various social values.

Contemporary urban design has evolved beyond pure forms and aesthetics. It is facing challenges of changing social needs under temporal and spatial uncertainty, multiple stakeholders for various ends and individual experience. Regarding the tem-

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https://doi.org/10.1007/978-3-030-49618-0_4

Table 4.1 The evolution of urban design practice and theories

Time	Ethos	Characteristics	Examples
Before seventeenth century	Social norms and religious beliefs	Cities are designed with squares, grids, memorials as physical embodiments of the social norms or religious beliefs of Greek democracy, European medieval feudalism, Catholicism, and the renaissance	• Hippodamus of Miletus in ancient Greece was designed with orthogonal regularity to echo rational social order • Ancient Roman cities were designed with squares, colonnades, and monuments in honor of military and sovereign empowerment • Medieval cities were guarded with defensive walls and castles and centered around churches, markets, and plazas • Cities of the renaissance period were built with secular architectures (e.g., Florence)
Eighteenth century–early twentieth century	Geometry as an aesthetic	Urban design follows aesthetic principles regarding green space and boulevards with axial and symmetric patterns	• L'Enfant's 1791 plan for the "Federal City" (Washington, D.C., USA) • City Beautiful Movement of North America in the late nineteenth century • Urban parks movement of North America in the late nineteenth century • Camillo Sitte (1889) published the book *City Planning according to Artistic Principles* to examine the traditional approach to urbanism of medieval and renaissance Europe, especially regarding public spaces and street patterns (Camillo 1965) • Haussmann's renovation of Paris between 1853 and 1970 • Canberra City Plan, 1911
Early twentieth century–mid-twentieth century	Efficiency and function	Urban design was greatly influenced by the Athens charter in 1933 and the modernist movement in the early twentieth century, and it focused on functional zoning, grid street networks, and space order, using new techniques of construction and transportation. However, they were still upsized architectural designs, contributing little to solving urban social problems	• Ville Radieuse by Le Corbusier, 1933 • Master plan for Chandigarh, India, in the 1950s • 1956 pilot masterplan for Brasilia, Brazil, by Lucio Costa

(continued)

Table 4.1 (continued)

Time	Ethos	Characteristics	Examples
1960–1980	Integration of multiple social values	Influenced by the charter of Machu Picchu in 1977 as an update to the charter of Athens, urban design shifted from function and efficiency schemes to dynamism	• Team 10 at the congress of C.I.A.M. in 1954 proposed an urban planning approach to consider how people group into houses, streets, districts, and cities • Lynch (1960) published the book *The Image of the City* in 1960 with regard to legibility and the reduction of urban design theory to five elements • Jacobs (1961) published the book *The Death and Life of Great American Cities* in 1961 and stressed the importance of the street vitality of cities • Alexander (1965) published the essay "A City Is not a Tree" in 1965, proposing the concept of the semilattice as a complex network analysis of city patterns and structures (Alexander et al. 1977) • Rossi (1982) published the book *The Architecture of the City* in 1966 to shift urban doctrines of modernism to a rediscovery of traditional European cities and to define the place as the juxtaposition of space and event • Rapoport (1977) published the book *Human Aspects of Urban Form* in 1977 and proposed the man-environment approach to examine how people perceive the city through social, cultural, and ethological concepts
1990–2010	Integration of ecological and landscape dimensions	Urban design concept was broadened to include landscape consideration and upscaled to the regional level	• McHarg's (1971) book *Design with Nature* pioneered the concept of ecological planning and created the composite map method for environmental suitability analysis of different types of development and use • Simonds (1978) released the publication "Earthscape: A Manual of Environmental Planning" in 1978 • Waldheim (2006) proposed the theory of landscape urbanism to examine how landscapes emerge as models and mediums of cities

poral dimension, urban design can be hardly implemented without any deviation from the blueprint, and it will be affected by unforeseen socioeconomic factors, in turn generating new requirements for urban design with the change of time. Regarding the spatial dimension, different stakeholders will impose their own needs on the space shaping; thus, urban design must respond to various behavioral demands for public participation. Fortunately, the accumulation of multiple sources of big data through urban development and human interactions creates an opportunity for us to better understand how urban design should adapt both temporarily and spatially.

The emergence of high-granularity big data helps to deepen our understanding of existing urban context. It has formed a data spectrum on urban land use and functionality, urban forms, social media, transportation and mobility, and building environments on different scales of urban districts, land parcels, street spaces, and buildings (Table 4.2). These data can be applied to field surveys, context analyses, draft designs, and visualization during the process of urban design and planning.

Urban big data are used for smart cities construction through information communication technology (Albino et al. 2015). The concept of smart cities evolved from wired cities (Dutton et al. 1987), telecities (Fathy 1991), cybervilles (Horn 1998), Digital cities (Ishida 2000), and techno cities (Kargon and Molella 2008). For smart cities, the relationships between people and people, between people and objects, and between objects and objects can be regulated through their interconnections. The corresponding data can be collected from sensors and processed to enhance smart transportation, crowdsource geo-information operations, and even encourage public participation for smart decisions regarding urban management.

Long and Shen (2015) developed the methods of Data Augmented Design (DAD) that pioneered data analysis to support urban design processes. The application of big data in urban design is facing both opportunities and challenges. On the one hand, it makes post-positioned feedback possible for urban design: when the construction of a design is implemented; space can be measured for how it is utilized, in turn providing evidence for future design and space adjustments. It either supplements the conventional urban design process by elites with rigid blueprint enforcement and little feedback, or it complements traditional public participation, which only involves pre-positioned feedback. On the other hand, despite urban big data's advantages in the macroscale context of analysis and planning evaluations due to large spatial data coverage, high data granularity, frequent data updates, and the precise analysis at the microlevel remain challenges. A good urban design at the microlevel must usually consider ad hoc human factors, and it used to be solved by designers' and planners' careful observations and prudential judgments beforehand. However, customized sensors for collecting this ad hoc data can also be helpful to a precise analysis of human behaviors and interactions between humans and spaces, such as visitors' profiles during popular times, how people utilized the space, and people's site preferences. These data tend to have short feedback cycles and high sensitivity, and how to establish a workable sensor platform and precise data analysis system is a crucial question.

Therefore, based on the concept of DAD, we propose the concept of data adaptive urban design, which will be adjusted and rectified dynamically according to post-positioned feedback and precise data analysis. It runs through the cycle of

Table 4.2 The application of big data in urban planning and design at different scales

	Big data categories				
	Land use and functionality	Urban form	Social media	Transportation and mobility	Building environment
	Land use, remote sensing images, points of interest	Road networks, figure grounds, building heights, floor area ratios, street view images	Microblogger/ Twitter, Facebook, Dazhongdianping/ Yelp, Booking/ Agoda, Trip Advisor, Airbnb	Bus and metro card data, Didi Chuxing/Uber, taxi data, GPS, mobile phone data, heat maps	Energy consumption, water consumption, building physical environment (heat, sound, and light), air pollution
Urban districts	Construction areas of cities and towns, construction intensity, construction suitability analysis, urban growth boundaries, division of urban functional districts	Road network density, space syntax analysis of street networks, urban open spaces, skylines, landscape corridors	Popular places, reviews, sentiment indices, city images	OD matrix, popular places, regional accessibility	Environmental suitability analysis, energy consumption analysis, urban ventilation corridors
Land parcels	Land use mix, primary land use category	3D building forms, floor area ratios, site transportation	Visitor volume, revenue, reviews, heat maps, peak hours, visitor profiles	Trip generation and attraction, passenger volumes, accessibility	Microclimate
Street space	Density and mixed use of street-front retail	Enclosures, transparency, coherence, walkability, pedestrian flow	Pedestrian volume, revenue, reviews, heat maps, peak hours, visitor profiles	Mobile and pedestrian traffic volumes	Visible green index, green space ratios, shade, noise
Buildings	Function of space usage	Architectural style, site context	Reviews, popular times, perceptions, reviews, visitor profiles	Visitor flow, site accessibility	Energy consumption, sunlight and daylight in buildings

prerequisite data analysis, draft design, space intervention, data feedback, and design adaptation. Since a data adaptive urban design workflow relies on the measurement of existing conditions, it is more suitable for urban inventory space intervention. Moreover, different types of urban space entail different data adaptive urban design strategies. For the urban space necessitating frequent interventions and changes, data feedback should be short term with high responsiveness to measure the demand for future space adaptation. For the urban space shaped by significant interventions and requiring more enduring maintenance, data feedback must be long term to gauge whether the urban design is effectively implemented. This chapter is organized as follows. In Sect. 4.2, we illustrate the framework of data adaptive urban design by defining attributes, depicting workflow, and listing tools, and in Sect. 4.3, we further illustrate the street space design in Shanghai Hengfu historical district as a case study of a data adaptive urban design for inventory space. Finally, we conclude with major points and discuss the future research directions in Sect. 4.4.

4.2 The Framework of Data Adaptive Urban Design

4.2.1 Attributes

There are four fundamentals of data adaptive urban design. (1) The data feedback is post-positioned and collected after the first found of urban design implementation. (2) Short-term and medium-term space interventions are applied based on more frequent data feedback. (3) The cycles of draft design, space intervention, and data feedback form a constant process in an up-spiral continuation with dynamic balance. (4) It necessitates data and sensor infrastructure construction to guarantee customized data collection and precise analysis. As shown in Fig. 4.1, in the earlier stage of DAD, the big data from multiple sources can be integrated for surveys, modeling, and forecasts to support the design idea formulating process. It not only brings a greater rationale to the subjective designing process, but it also triggers creativity for designers through more detailed data observations. In the later stage of DAD, namely data the adaptive urban design stage, medium-/short-term urban design updates for space interventions are determined by the feedback from precise analysis of customized data. Through the periodic optimization based on post-positioned feedback, some unforeseen, ominous results can be identified and thus avoided.

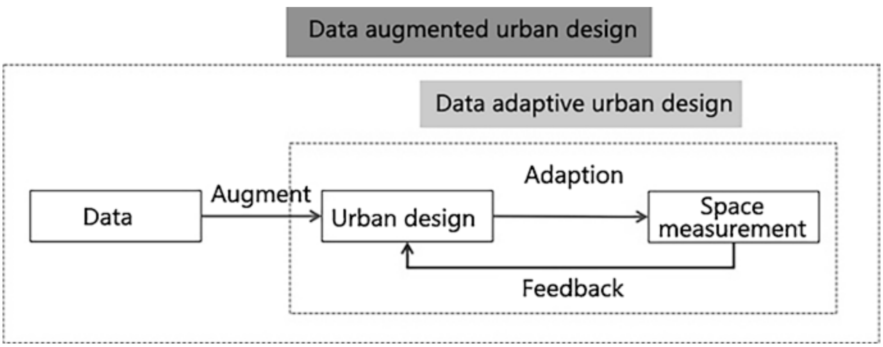

Fig. 4.1 Concept of data adaptive urban design

4.2.2 Workflows

The key to data adaptive urban design is that data feedback frequency varies from space to space and from time to time, associated with different space intervention strategies. Figure 4.2 shows the workflow of three major stages of data adaptive urban design processes. In stage 1, according to pre-positioned big data collection in Table 4.2 for the analysis of site strengths, weaknesses, opportunities, and challenges, space is classified into different categories by dimensions of variability and malleability. In stage 2, design as space intervention is formulated for different categories of space, and then data are collected for short-/medium-term feedback. Based on this feedback, the design can be adapted accordingly in a continuing cycle. In greater detail, for space of low variability and high malleability (e.g., urban major nodes, districts, and corridors), a base plan A should be implemented with coherence. Through medium-term data feedback, we must check whether current space A' after implementation deviates from initial plan A. If it does, space interventions will be rectified to enhance alignment. For spaces of high variability and low

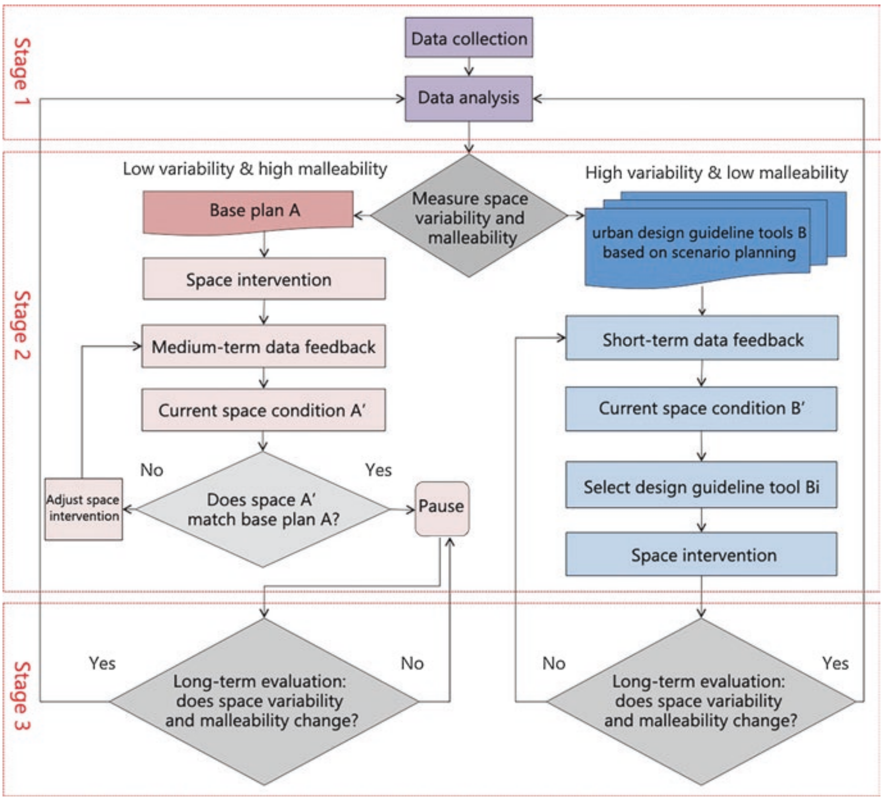

Fig. 4.2 Workflow of data adaptive urban design

malleability (e.g., streets and land parcels with frequent environmental or functional changes), a series of urban design guideline tools B will be generated based on scenario planning. After measuring the conditions B' with short-term data feedback, the suitable design guideline tool Bi will be selected from B for space interventions. Thus, design tools will be periodically changed and dynamically adapted to the changing conditions. In stage 3, there is a long-term space reclassification that returns to stage 1. Either space A or space B can shift into each other after many rounds of stage 2 cycles. Therefore, space must be reevaluated for a new round of classification based on variability and malleability in stage 1 to receive different urban design strategies and interventions next.

4.2.3 Data Tools

Feedback Data for Space Measurement

In the earlier stage of DAD, data analysis supports the formulation of design ideas. The data tools include urban modeling, spatial statistics, spatial data mining and visualization, and parametric design. For the stage of data adaptive urban design, space measurement is customized for the specific urban design and space categories, and it is dependent on periodic data feedback. The data feedback for space measurement can be obtained from web-source and app-source data of lower granularity and installed sensors with higher granularity. Table 4.3 summarizes three types of feedback data for space measurement: human behavior data, space function and quality data, and building physical environment and public health data.

Real-Time Data for Adjusting Interactions Between People and Space

Other than the feedback data for medium-/short-term space measurement, the real-time data are also necessary for luring interactions between people and spaces, which will further facilitate automatic human behavior adaption to space usage. For example, a special road pavement can record pedestrian information when people are walking on it, such as pedestrian flow, length of stay, walking paths, and passengers' profiles. This information will be demonstrated through data visualization on building façades, lighting shows, and music to assist people to make real-time decisions about where to go and stay. In addition, through parking searching apps, not only do drivers obtain real-time information to make better parking decisions concerning parking costs and navigation convenience but also city governors can alleviate peak-hour congestion with certain marketing strategies.

Table 4.3 Categories, methods, and contents of different detected big data for spatial feedback

Categories of feedback data for space measurement	Sources	Contents
Human behavior data	Web source	Sentiment index, reviews, reported road congestion and accidents, trip patterns
	Wi-Fi sensor	Human profiles, behavioral preferences
	Face camera	Facial impression and sentiments, behavior analysis, accent identification
	Checkpoint and tracking sensor	Traffic flow of pedestrian and vehicles, length of stay, movement path, passenger profiles, interaction devices
	Transportation and mobility smart phone app	Parking, searching, directing, and matching app, ride hailing and ride sharing app, bike sharing app (the travel behavior and trip paths can be traced for understanding trip patterns)
Space function and quality data	Street image camera and analyzing platforms	Automatic street image analysis of street environment (enclosure, transparency, coherence, walkability, building façade, plantations, billboards) based on periodic and automatic image capture and updates
	Geo-information sensor and processing platforms	The major function of land parcels and streets, land use mix, density of street-front retails, street network patterns, nearby facilities, figure ground and road morphology
Building physical environment and public health data	Air pollution sensor	Monitoring air pollution index of construction sites, streets, and open spaces
	Sound, light, and heat barometer	Monitoring comfortableness of streets, parks, and other open spaces

Relationship Between Feedback Data and Real-Time Data

The difference between feedback data and real-time data is that the former is used for adapting space interventions to space changes, while the latter is used for adapting human behaviors for space utilization to space changes. Therefore, the feedback data provide information about how space must be intervened in by medium-term urban design plans and short-term urban design guideline tools. Further, the real-time data provide information with interaction devices for people to make instant decision to optimize space utilization. Figure 4.3 presents how these two data tools are integrated with a data adaptive urban design. The data platform not only measures space for future pace interventions but also operates as a medium between humans and space.

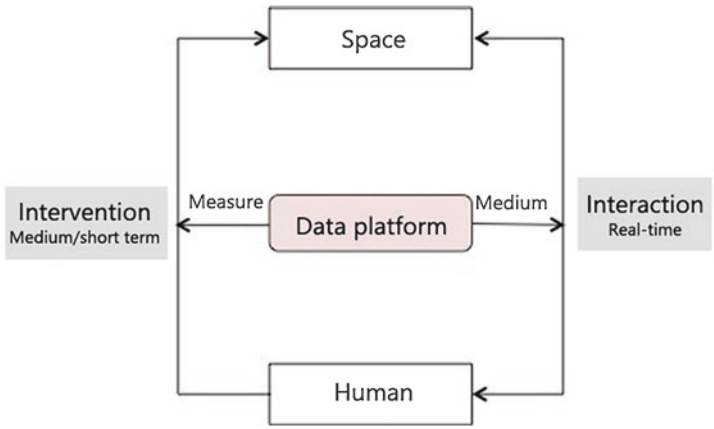

Fig. 4.3 The interaction mechanism of space and humans

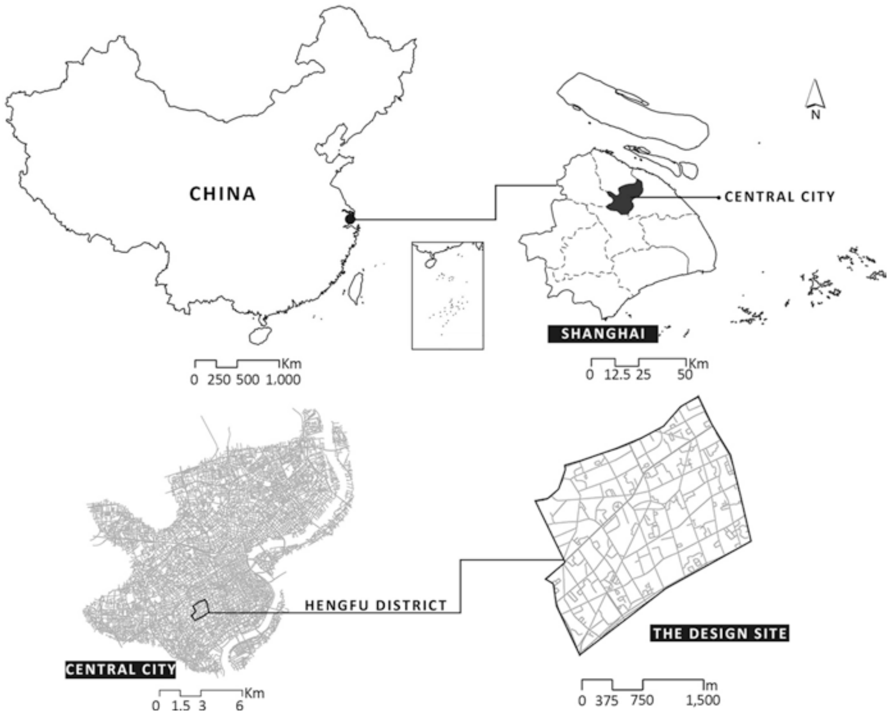

Fig. 4.4 The location of the design site

4.3 Case Study: Street Space Urban Design of Shanghai Hengfu Historical District

4.3.1 Design Site

We apply a data adaptive urban design method to the redevelopment of inventory urban space, with a case study of Shanghai Hengfu historic district (Fig. 4.1). Hengfu refers to the "Hengshan Road—Revival Road" historical and cultural protection area, which is one of the first 12 historical and cultural landscape protection areas in Shanghai, China, in the form of legislation. As the largest protected area in Shanghai, Hengfu has a profound historical and cultural heritage, and it is the birthplace and carrying area of Shanghai's urban culture.

4.3.2 Concept and Framework

We focus on the system of linear street space and open space and examine how this space can be promoted with adaptive sustainable development driven by urban big data. Figure 4.5 illustrates the general framework. First, by integrating big data measurements with traditional field surveys and conventional data, we analyze the characteristics of various streets and classify them into category A, the current features of which will be strengthened and not changed for a long time, and category B, which requires more frequent space interventions. Second, the customized data platforms (sensors, webs, and apps) are established according to street categories and characteristics for specific data collection and processing. How urban design is implemented and how people react to different urban space will be measured through data feedback under certain cycles. This data platform also promotes interactions of multiple stakeholders, such as residents, planners, governors, and enterprises. Then, for street category B, we propose dynamic urban design guidelines based on scenario planning. Finally, for street category A, we devise a base plan that will be implemented and maintained for a longer time, and it will be strengthened and optimized through medium-term data feedback.

4.3.3 Site Context Analysis

The site context is analyzed through multiple sources of data (Table 4.4): official master plans (master plan of the city of Shanghai, historical street conservation plan of Xuhui District), social media data (Weibo sentiment index map in Fig. 4.6, review of places on the Xiecheng website), land use and transportation data (heat maps, job-house ratios), socioeconomic data (rentals, housing prices, restaurant consumption data for the Dazhongdianping app in Fig. 4.7), urban spatial data (urban development

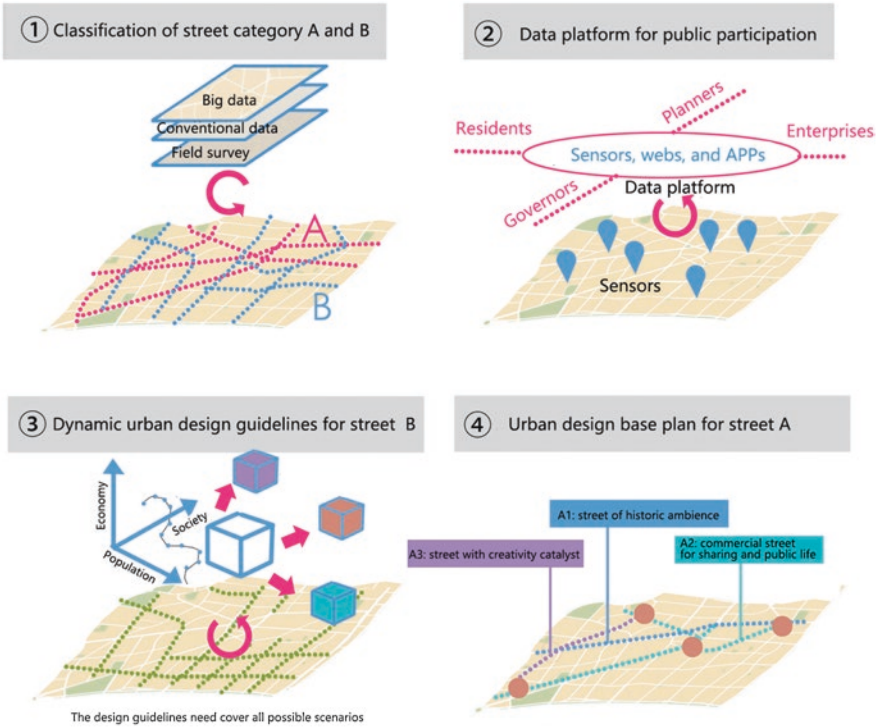

Fig. 4.5 Design concept and framework

boundary modeling results, nearby facilities within a 15-min walking distance in Fig. 4.8), and site survey data (street environment perceptions of residents, travel surveys, traffic volumes). After the comprehensive site analysis, we pioneer the goals for Hengfu historic district as the pilot district for the display of Shanghai's culture and history, incubators for technology and inventions, and places to live with friendly street spaces. Accordingly, we generalize four major strategies: enhancing site identity, promoting the function and space organization of major nodes and corridors, setting standards for street space utilization and street-front retail operation, and providing abundant offerings of public facilities.

4.3.4 Street Score and Classification of Street Categories

To measure street space with multiple sources of data, we establish the street score, with 20 indicators on four dimensions of attraction, safety, comfortableness, and historic features (Table 4.5). The indicators of the street score are weighted by residents' preferences from the survey. Figure 4.9 presents the calculation results for each street score indicator.

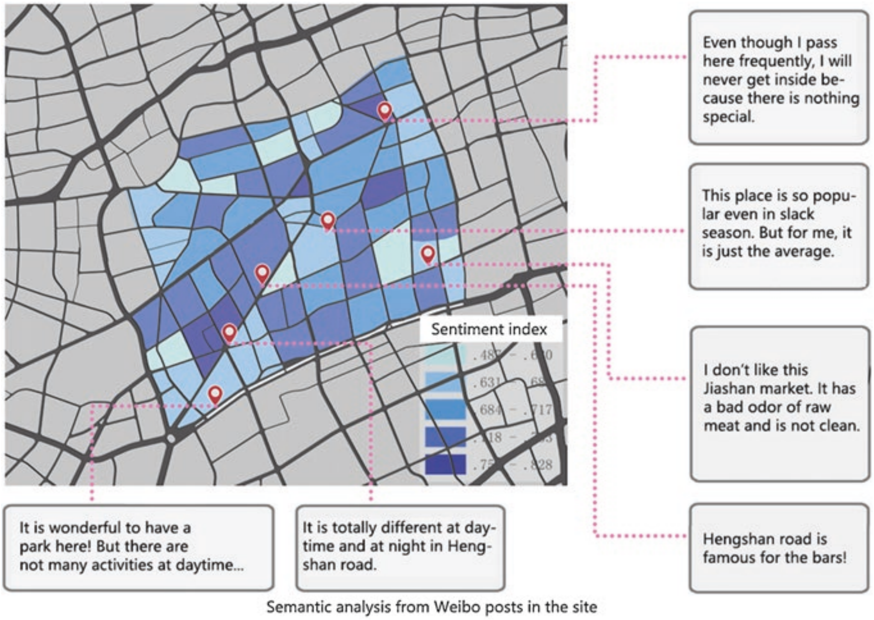

Fig. 4.6 Mood index based on micro blog data analysis

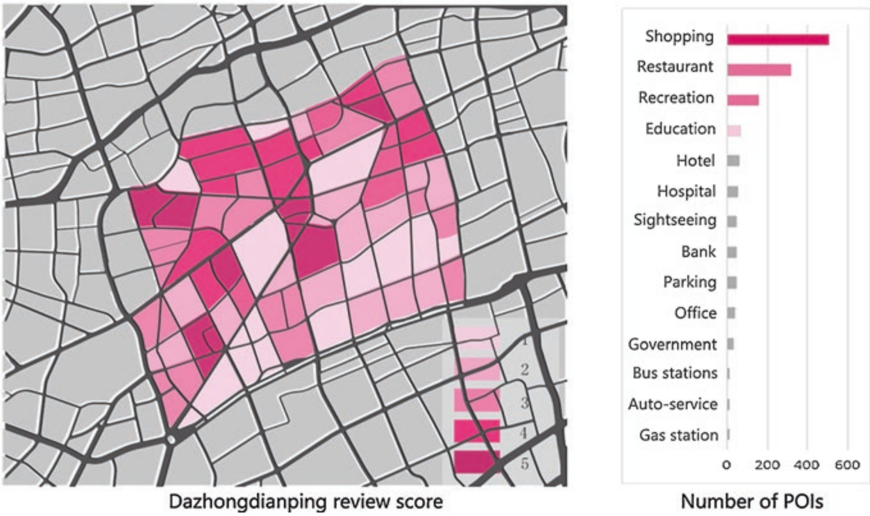

Fig. 4.7 Dazhongdianping review data analysis and POI statistics

Table 4.4 Indicators and data sources

Indicator	Description	Data	Data Source	Analysis method
Urban structure	Land use category	Land use data	Planning bureau	Identify concentration of various functionalities
Public perception of street environment	Social media sentiment index	Weibo post	Sina Weibo	Natural language processing
	Social media word cloud	Weibo post	Sina Weibo	Natural language processing
Public perception of urban space	Level of satisfaction	Shop review score	Dazhongdianping	Review score statistics
Land economics	Average shop consumption	Reviews	Dazhongdianping	Reviews statistics
	Average rent amount	Rent	Anjuke	Rent statistics
Accessibility to public facilities	Number of facilities accessed within 15-min walking	POI	OpenStreetMap	Isochrone analysis
Space intervention suggestions by residents	Preference on future facilities	Survey data	Resident survey	Survey statistics
Street quality perception by residents	Street quality evaluation and reasons	Survey data	Resident survey	Survey statistics
Street congestion	Number of motorized vehicles, non-motorized vehicles, and pedestrians per 10 min	Traffic flow	Site survey	Traffic counts

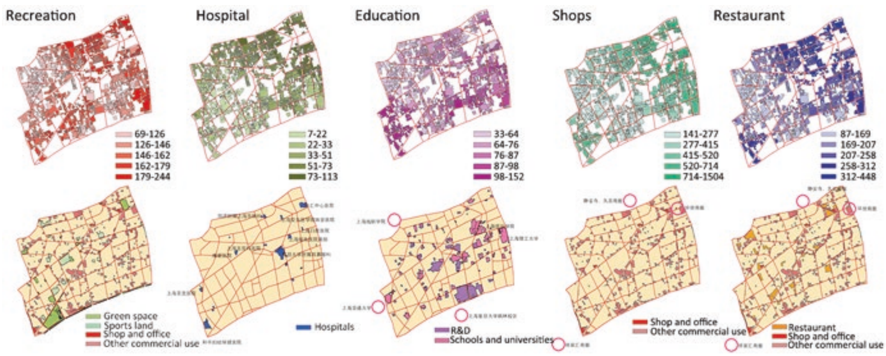

Fig. 4.8 The statistics on numbers of life service POIs within a 15-min walking distance for each residential block (top) and the land use pattern (bottom)

Table. 4.5 Walk score evaluation criteria

Street score dimension	Indicators	Data and processing methodology
Attraction	Distance to nearby facilities	The distance from the middle points of road segments to nearby shops, restaurant, and public facilities
	Land use mix	By setting the 100-m buffering zone along the street, land use mix H is calculated as: $H = -\sum_{i=1}^{N} P_i * \log p_i$; $P_i = A_i/A = A_i/ \bullet {}_i^N A_i$, where P_i is the percentage of point of interest i, A_i is the number of point of interest i, and A is the number of all points of interest
	Weibo sentiment index	Semantic analysis of the Weibo post inside the 100-m buffering zone along the street
	Street-front retail density	Division of the number of points of interests of the stores on the ground floor by the street length
Safety	Traffic congestion	The congestion level on the Gaode Map during 7 am to 11 pm on a typical working day
	Sidewalk width percentage	Ratio of sidewalk width to road width
	Bicycle lane width percentage	Ratio of bicycle lane width to road width
	Pedestrian walking environment	Whether there is isolation between motorized vehicles and sidewalks (identified on street view images)
	Street integration degree	Calculated in SPACE SYNTAX software
	Street network density	The total length of street networks within the 200-m radius buffering circle around the middle point of the street
Comfortableness	Visible green index	The average green ratio of street view images at points at 50-m intervals along a street
	Green space	Whether there is green space where people can walk (identified on street view images)
	Bicycle lots	Whether there are bicycle lots beside the street (identified on street view images)
	Sanitation	Whether streets are clean (identified on street view images)
	Street ornaments	Whether streets have furniture and lighting to create a friendly ambience (identified on street view images)
	Motorized vehicle parking	Whether there is roadside parking for motorized vehicles (identified on street view images)

(continued)

Table. 4.5 (continued)

Street score dimension	Indicators	Data and processing methodology
Historic features	Buildings	Whether the fences along the streets have continuity, the sidewalks are covered by trees, and buildings are arrayed with alignment and display a harmonious and historic feature (identified on street view images)
	Small open space	Whether there is a setback in front of the building as a public space for the neighborhood (identified on street view images)
	Urban nodes	Whether there are urban nodes along the streets as a major public space (identified on street view images)
	Access ways of neighborhoods	Whether the neighborhoods have access ways while maintaining good privacy

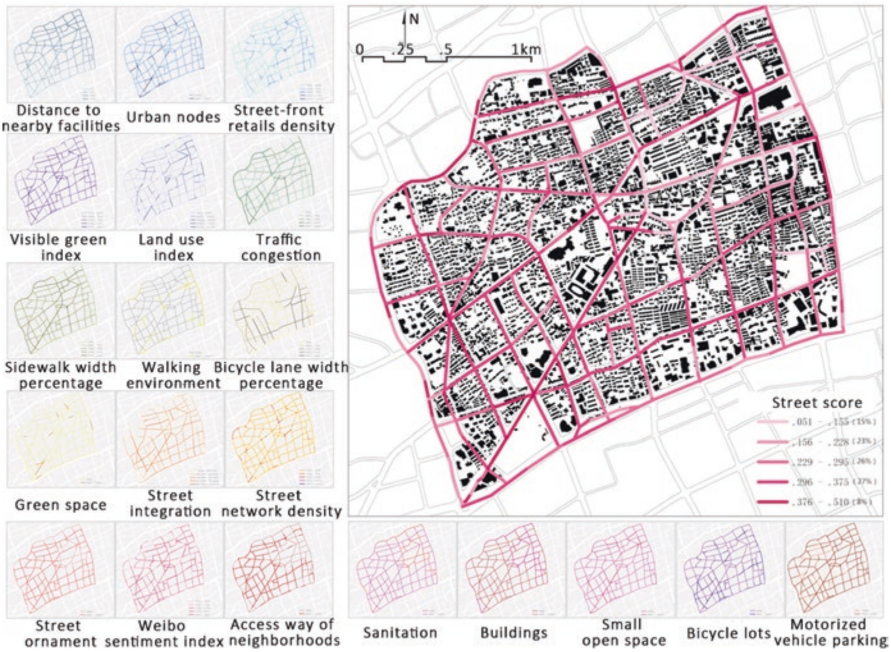

Fig. 4.9 Street score results

As is shown in Fig. 4.10, based on the street score, surveys on people's perceptions of the street environment, traffic volume data, semantic analysis of social media data, and official plans of street development in Hengfu historic district, we select the streets of higher scores and reviews and further divide them into category A1 (streets of historic ambience), category A2 (commercial streets for sharing and public life), and category A3 (streets with creativity catalysts). These streets will be developed as primary public spaces with its major identity further strengthened in

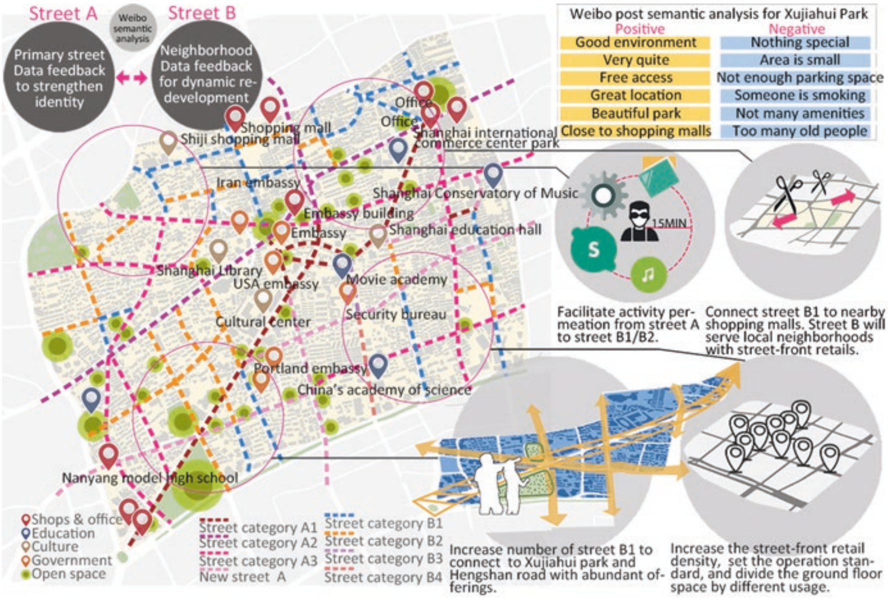

Fig. 4.10 Classification of type A and type B streets

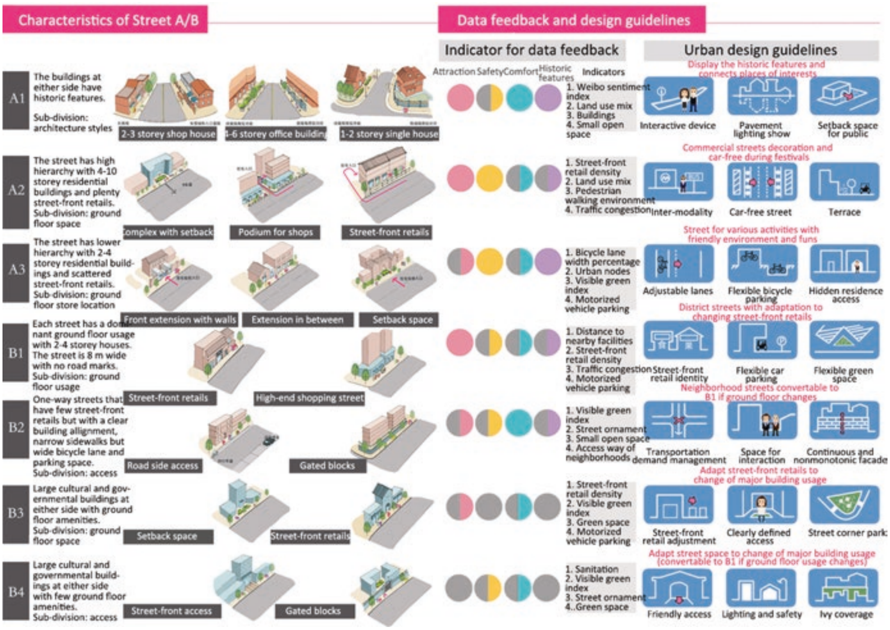

Fig. 4.11 Spatial form analysis, big data indicators, and design guidelines for type A and B streets

the data feedback process. For streets with lower scores and reviews, we tag them as category B for future adaptation through data feedback processes. These streets provide institutional services and cultural facilities at the neighborhood level and are divided into categories B1 (residential streets with plenty of street-front retail), B2 (enclosed residential streets with little street-front retail), B3 (streets for offices and cultural facilities and with plenty of street-front retail), and B4 (enclosed streets for offices and cultural facilities and with little street-front retail)

4.3.5 Base Plan for Street Category A and Design Guidelines for Street Category B

For each street category A and category B, we set the indicators for data feedback and space measurement, and we propose the corresponding urban design guidelines (Fig. 4.11). For street category A, there will be a medium-/long-term base plan under the framework of urban design guidelines. Further, the data feedback is for real-time monitoring and rectification of any plan deviation. For street category B, which has high variability in a short time, urban design guidelines function as the dynamic intervention for street redevelopment according to the changing demand, as indicated by short-term data feedback. For example, category B1's street environ-

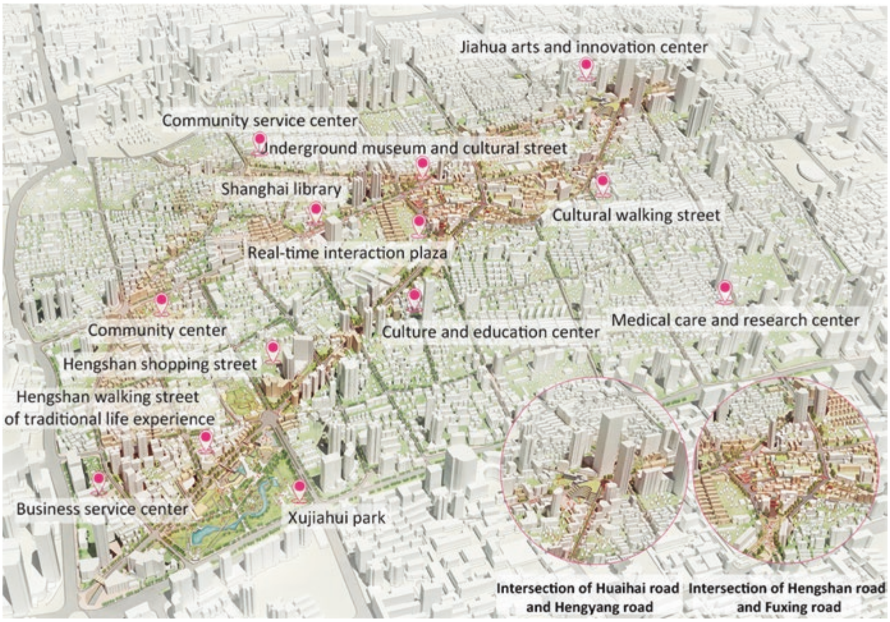

Fig. 4.12 Master plan of type A streets

Fig. 4.13 Bird's eye view of type A streets

ment will adapt to the change in street-front retails, and category B2 will be evaluated based on whether it has been converted into category B1 periodically.

Additionally, for street category A, we propose a preliminary base plan. Figures 4.12, 4.13, and 4.14 show the corridors for street categories A1, A2, and A3 and three nodes for public space, traffic junctions, and creativity incubation, respectively. For category A1, the streets are divided into various segments with different topics, such as experience of traditional life in Hengfu district, real-time interaction with buildings and street environments, and cultural walking streets. For category A2, the commercial streets are designed with sharing spaces in front of the buildings to create a public space for a variety of offerings. For category A3, streets connect two creativity centers at the end of Wukang Road and Tianping Road to facilitate the permeation of small incubators into the community for neighborhood revitalization.

4.3.6 Online Data Platform

Moreover, we construct an online platform for data display and interaction among multiple stakeholders (Fig. 4.15). It contains four subplatforms: real-time monitoring, data visualization, design and plan display, and public participation. The subplatform of real-time monitoring will detect the passenger flow, public sentiment, and human behavior to provide information about how urban designs are

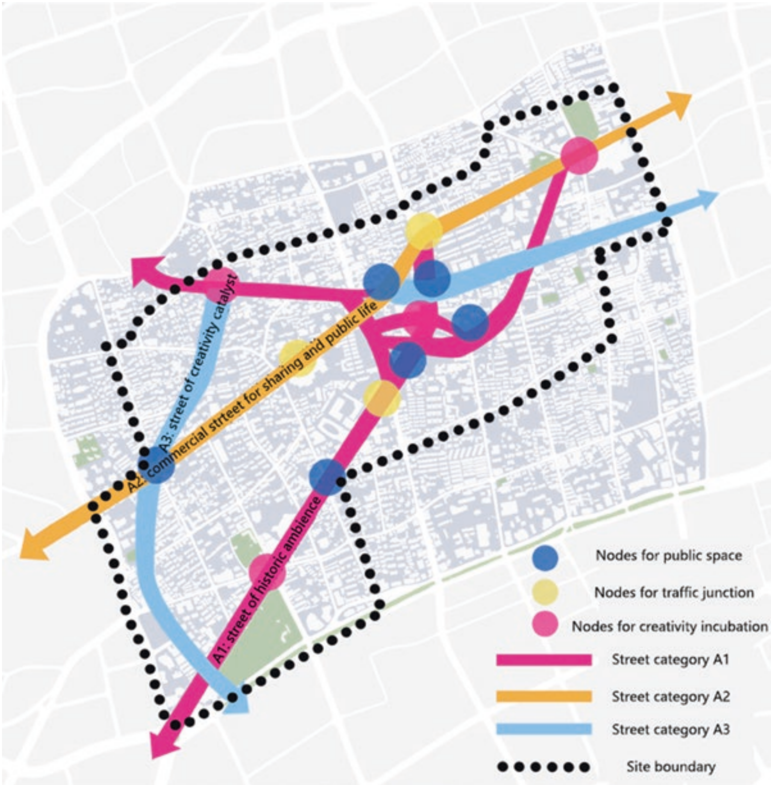

Fig. 4.14 Spatial structure of type A streets

implemented and whether there is a need for space adaption. The data include number of visitors per hour, visitors' profiles based on smart phone app data, hourly parking space utilization by camera data, and social media semantic data. The subplatform of data visualization will not only illustrate data information (transportation, housing price public service, and industry) of Hengfu District but also its relationship to surrounding area and comparisons with all of the other districts in Shanghai. The data will be updated at intervals of 6–12 months.

4.4 Conclusion and Discussion

This research is a typical application of DAD, in which multidata are analyzed to help better understand the design site. Based on the results, we propose a concept of data adaptive urban design and its methodology and application, and we apply it to the case study in Hengfu historic district. The data adaptive urban design integrates post-positioned spatial measurements and feedback into the process of urban plan-

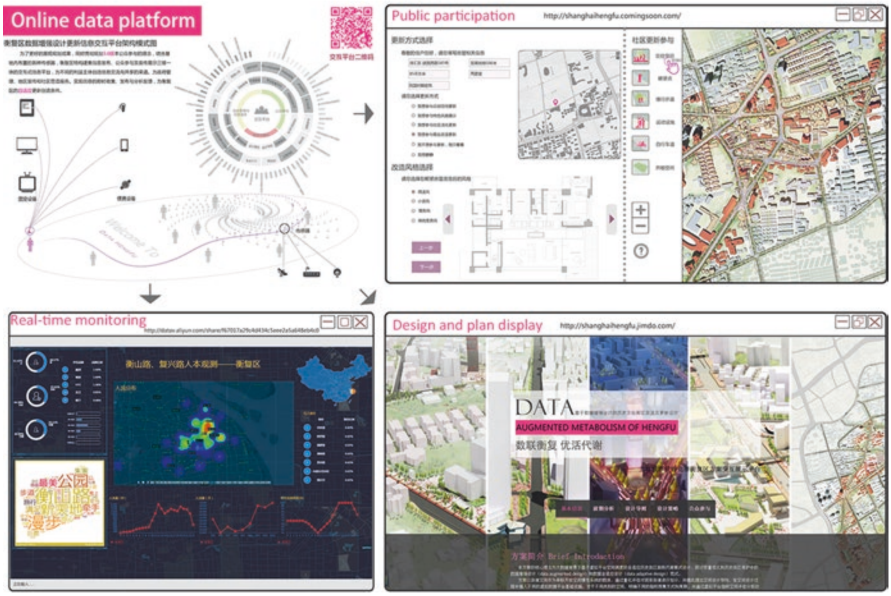

Fig. 4.15 Interaction website for information sharing and public participation

ning and design, which will convert the long-term planning evaluation into a short-term spatial intervention. By establishing a sensor infrastructure, we can obtain feedback from precise and customized big data to promote reciprocal interactions of urban design and spatial utilization. In this way, we can achieve the goal of DAD to use data to augment the design over the whole process.

However, there are still some future studies that should be conducted, including both theoretical and practice explorations, to understand how humans interact and behave to adapt to spatial changes. Theoretically, we will examine more data needed for other types of urban design and how data feedback can provide useful information for better space adaptation. Practically, we tend to build real sensor infrastructures and online data platforms for validation. Moreover, despite these limitations, this chapter only discusses the data adaptive urban design of street space in a historical district; future studies will explore its application to more urban redevelopment-oriented designs.

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Chapter 5
Multidimensional Data-Based City Images: Cultural Reactivation of Waterfront Industrial Heritage Design in Shanghai

Abstract There are many famous waterfront art and cultural districts in the world, among which the urban renewal of industrial heritage is an important topic. This chapter interprets another design case of the first type of Data Augmented Design (DAD), which takes the Minsheng Wharf in Shanghai as the design site. A wide range of multisource data is analyzed to identify the city image and specific problems. Based on above analysis, a comprehensive city image is revealed—memory, art, and life, which is also the main design concept throughout the design. This area is expected not only an elegant area where art exhibitions are held, but also a curtain in the daily life for local residents hosting a variety of events and activities in the future. Some design strategies are proposed to rebuild the cultural identity, make open-space oriented waterfront space, reshape cultural relics as daily places, and create daily oriented cultural moments. Finally, some simulations are modeled to adjust the design, which also reflects the core process of DAD.

Keywords New data environment · City image · Urban design · Industrial heritage · Waterfront

5.1 Introduction

5.1.1 Introduction to the Shanghai Urban Design Competition

Shanghai's new round of master planning has proposed the development goal of building a remarkable global city, making Shanghai a city of innovation, a city of humanities, and a city of ecology. In Shanghai, where the city has entered the era of stock development, it is worth studying and exploring how to utilize and revitalize the existing land, promote organic urban renewal, enhance the urban quality, and realize the transformation of urban development. The "Shanghai Urban Design

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Challenge" design competition is held to promote the application of big data to innovations in technology, management, and methods of urban design.

Sponsored and hosted by the Shanghai Municipal Planning and Land Resources Administration, the Challenge is based on the actual situation in Shanghai. Each year, a number of influential public or livelihood-related projects are selected, which are of public interest and have great impacts. Proposals and ideas are solicited from all over the world through the Internet to form a brand of urban planning work with the innovative influence of Shanghai city. Since 2016, there have been two "Shanghai Urban Design Challenges," attracting hundreds of teams/individuals from more than 30 cities at home and abroad, which have greatly enriched the exploration of data-driven urban design and urban renewal in Shanghai.

In 2018, the third Shanghai Urban Design Challenge was officially launched. The competition was based on the principle of "openness, sharing, and innovation." It combined new thinking such as "Big Data, Internet +" with the support of multi-source data and open platforms, based on urban design projects exploring new urban design methods that are helpful in urban renewal.

5.1.2 Site of Design

To actively implement the requirements of the Shanghai Urban Planning and Land Resource Administration Bureau (2018), the 2018 Shanghai Urban Design Challenge focuses on the reconstruction of two important river waterfront areas in the city—namely, the Huangpu River and the Suzhou River. Through the renovation of the waterfront areas, the function and quality of the waterfront space will be further enhanced, making it a world-class waterfront activity zone. The Huangpu River was selected as the design site. For this competition, participants and their teams are expected to use the multisource data provided by the competition organization and are encouraged to bring or integrate city-related big data resources to assist in the formation of an urban design scheme and provide innovative design ideas for the transformation of urban renewal areas.

In 2017, Shanghai completed a public space construction project on the east bank of the Huangpu River, achieving a three-lane system for walking, running, and cycling. The design site in this chapter is an important node in the southern part of the east bank of the Huangpu River. The project aims to improve regional public functions, optimize regional public space systems, and enhance the public art atmosphere and environmental quality. The area will be built into a waterfront public activity area that citizens can fully enjoy. The design scope is defined by Minsheng Road, South Bank of Huangpu River, Inner Ring Elevated Road, and Pudong Avenue, covering an area of approximately 64 hectares; the coastline of the riverside is approximately 1.1 km (Fig. 5.1). The functional orientation from the upper-level planning of the site is to take the waterfront ecological leisure and cultural display as the core, reflect the renewal of the dock area, and involve the R&D office and the modern urban waterfront area.

The current design site is mainly composed of commercial offices, ordinary residences, and potential design areas for construction, including the Pudong riverside

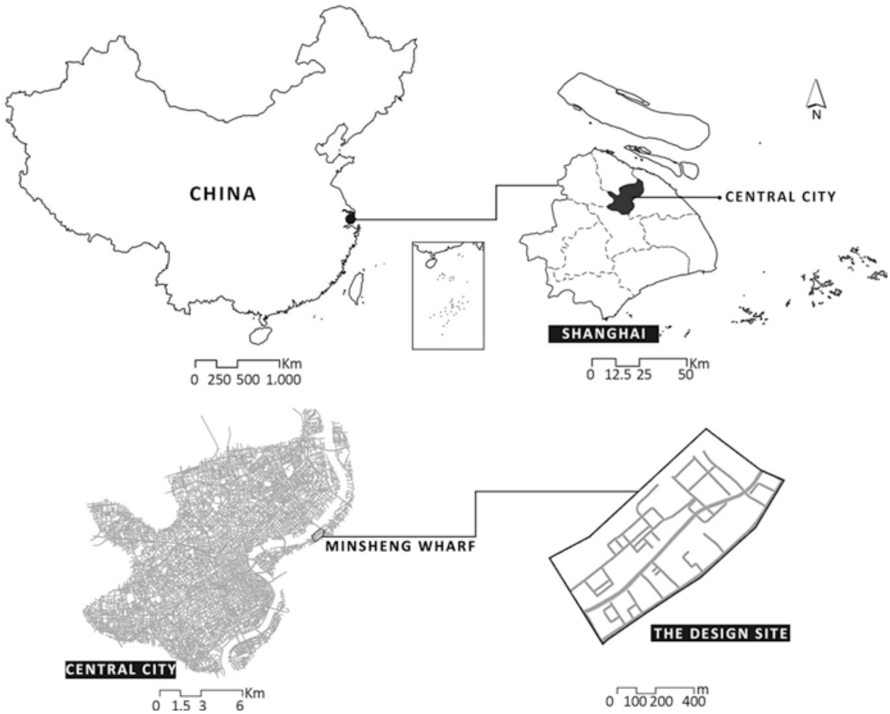

Fig. 5.1 The location of the design site

public space and the industrial heritage "80,000 Tons of Silos" that has hosted the "2017 Shanghai Urban Space Art Season" (Ma 2018) and other public facilities, as well as public housing communities and some high-end residential areas under construction. The waterfront public space in this area has been connected; however, the public space system from the hinterland to the riverside has yet to be completed, and the quality of the public space needs to be improved. In addition, multiple common space channels and nodes need to be further designed.

5.2 Research Framework

The development of big data brings opportunities and challenges to traditional urban design. First, the emergence of multisource data enables urban planners and managers to study the city accurately and quantitatively, helping to further understand the changes in urban spaces and individual activities in urban spaces objectively and systematically, thus guiding urban design (Batty 2013). Second, individual perceptions and needs present different spatial interests and behaviors, which need to be reflected by the dynamics and diversity in urban design. Long and Shen (2015)

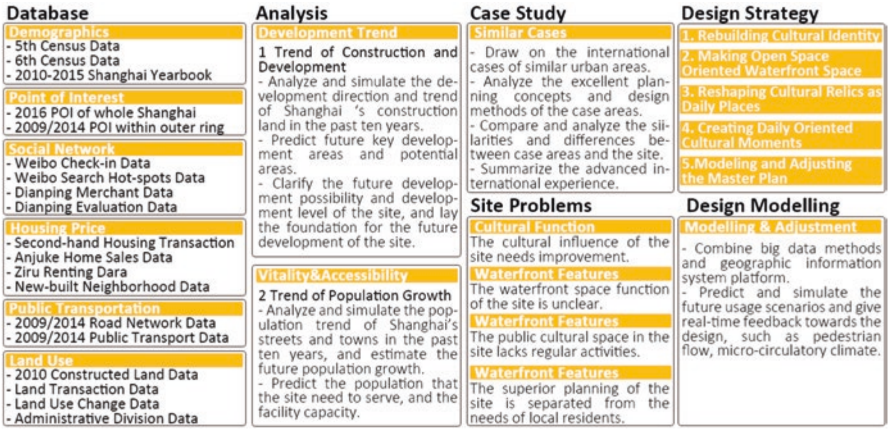

Fig. 5.2 Research framework

proposed the concept of DAD (Data Augmented Design), aiming at supporting the generation of urban design schemes through effective analysis of data to form more rational spatial decisions. Guided by the methodology of DAD, this research-oriented design is developed by collecting and analyzing big data for the site but not limited to it. The content of the DAD research process and technical framework in this design is as shown in Fig. 5.2. DAD is the foundation for understanding the actual site and helping to generate strategies and data analysis is performed throughout the whole design process. Moreover, multiple sources of data are used for horizontal case studies to draw forward strategic positioning and lessons to be learned. After the specific design, a data support system is applied to simulate the microenvironment scenario.

Data Source The authorities provide a variety of open government statistics data, including demographic and dynamic population distribution data, employment data, job structure, and business income data for various industries, distribution, and residential matching data of public service facilities with geographic information location, OD data for rail transit stations with geographic information location, the commuting data for residents, and CAD-format data of land use current status, and they also provide multiplatform emerging big data, such as the grid data from the Gu Dong app (a sport record app) motion data.

Through data mining and collating work, we add and use multisource data to analyze the existing conditions and find problems at the site from multiple perspectives (Table 5.1). The data range from traditional data such as urban statistical yearbook data (the Fifth Census data, the Sixth Census data, Statistical Yearbook of Shanghai for years), urban land use data, and urban planning data (GIS data of 2010 Shanghai urban land, land transaction data, land use change data, and administrative division data) to new data such as urban public transport data (Shanghai urban road network data, GIS data of subway stations, bus stops, and bus lines over the years),

Table 5.1 Indicators and data sources

Indicator	Description	Data	Data Source	Analysis method
Functional aggregation	Density of different functions	POI	Baidu Map	Kernel density tool in ArcGIS
Traffic accessibility	Service area coverage	Roads network	Baidu Map	Network analyst tool in ArcGIS
Expansion trends	Build-up area in different years	Urban boundary	Remote sensing images	Visualization
Population gathering	Population density	Statistical data	Yearbook	Visualization
Environmental comfort	Thermal comfort	Meteorological data	China Meteorological Administration	Simulation
Local microclimate	Block thermal environment	Meteorological data	China Meteorological Administration	Simulation

POI data (Shanghai citywide POI data for years, POI specific distribution data for recent years), emerging social network data (Shanghai Weibo check-in data, Weibo search hotspot data, DianPing shops and stores data, DianPing shopping review data), and multiplatform real-time house price data (second-hand housing transaction data within the Shanghai central urban area, new and second-hand housing sale data on the Anjuke website, housing rental data on the Ziru website, and Shanghai new residential community data in recent years).

Analytical Method The analysis method can be divided into three parts. The first one is the development trend analysis, including (1) construction and development regional prediction and (2) prediction of the population development trends. The second part is the analysis of vitality and accessibility, including (1) regional accessibility analysis and (2) analysis of site and surrounding vitality points. The third part is the basic evaluation method, including length and area measurements in CAD, calculations in CAD, geometric calculations in ArcGIS, raster map reclassifications, visual identification, and field trips.

Case Study Drawing on the international cases of similarly positioned urban areas, we horizontally analyzed the excellent planning concepts and design methods of the case areas, compared and analyzed the similarities and differences between the case areas and the site, summarized the advanced international experience, integrated regional characteristics, and finally achieved the outstanding trend and excellent orientation of the planning objectives.

Measurement and Diagnosis Beside the horizontal comparison of cases, the analysis of current status data and the spatial and policy interpretations of different scales, we also evaluated the spatial quality of the site. The core issues of the site are derived from four aspects, including site location, waterfront features, public space, and superior planning.

Concept and Strategy Combining the positioning, development goals, and common characteristics derived from the case studies, with core issues and renovation nodes derived from the analysis of the current status, we finally proposed the concepts and specific strategies of four issues: culture, openness, moment, and daily orientation.

Node Design We selected multiple types of key nodes for further detailed design, including traffic nodes, ecological nodes, external public space nodes, and internal public space nodes.

Modeling and Adjustment Combining big data science and geographic information system platforms, we predicted and simulated the future scenarios and gave real-time feedback towards our planning and design, such as prediction of pedestrian flow, microcirculatory climate (like temperature, humidity, wind speed, MRT), and other aspects.

5.3 Multidimensional Data-Based City Images

Using the above data and methods, we constructed a multidimensional data analysis framework for city images, which includes both physical environment and urban activities.

5.3.1 Cities: Macroanalysis for Site Identity

The mother river of Shanghai, Huangpu River, has witnessed the history of Shanghai's urban evolution. It has a large number of important nodes in the evolution of the city, such as the Bund, which is the important financial guarantee in past terminal transactions, and various types of shipyards, iron and steel factories, and so on. The Minsheng Wharf, which we focused on in this design, is also a very important part of these historical nodes.

The predecessor of Minsheng Wharf was built in the 34th year of the Guangxu Age (1871.08-1908.11) and has undergone two construction projects to reach its present scale. As the last legacy of this type of industry, 80,000 tons of silos became the swan song of industrial history and an indispensable part of Shanghai's industrial traits. The actual use of the silos lasted only 10 years, and there are no more such buildings. There are also old-fashioned communities such as the Lingyi or Linger communities, which represent the rapid development stage of Pudong changing from backwater land to valuable places since 1990. These development memories of Pudong are also the development memories of Shanghai. As a result, we used the first word "memory" to represent the rich historical value and images carried by the 80,000-ton silo area and the old-fashioned community.

To depict this image objectively, we conducted several comparative studies of historical data to illustrate these changes in Shanghai's urban form and functional development (Fig. 5.3). First, in order to identify the development stage of the site and future development opportunities, we analyzed and simulated the main development direction and trend of construction in the past ten years, and forecast future key development areas and potential areas. From the 1980s to 2015, the analysis of urban land use data in Shanghai's built-up areas shows that Shanghai has been expanding vertically from north to south along the banks of the Huangpu River. The vitality of the cities along the river is obviously enhanced, and thus, important nodes placed on the riverbank have great potential to attract people and be improved. To better provide a data foundation for the population that the site needs to serve, properly plan the capacity of the facility, and lay down sustainable development for the future, we analyzed and simulated the trends in population changes in towns and villages in Shanghai in the past ten years and calculated the scale of the future population. The study found that the increase in population density in Shanghai is mainly attributable to the urban expansion and the inflow of migrants from the surrounding cities and towns, and the population density changes little in the central city area. However, the population and dynamics around the silo area are increasing. Finally, using the POI data over the years, the dynamic distribution of Shanghai's cities presents the characteristics of vertical expansion along the riverbank in the early stage and later radiation expansion from the central area to the periphery (Li et al. 2018). We also conducted an analysis of regional accessibility, analyzed the regional

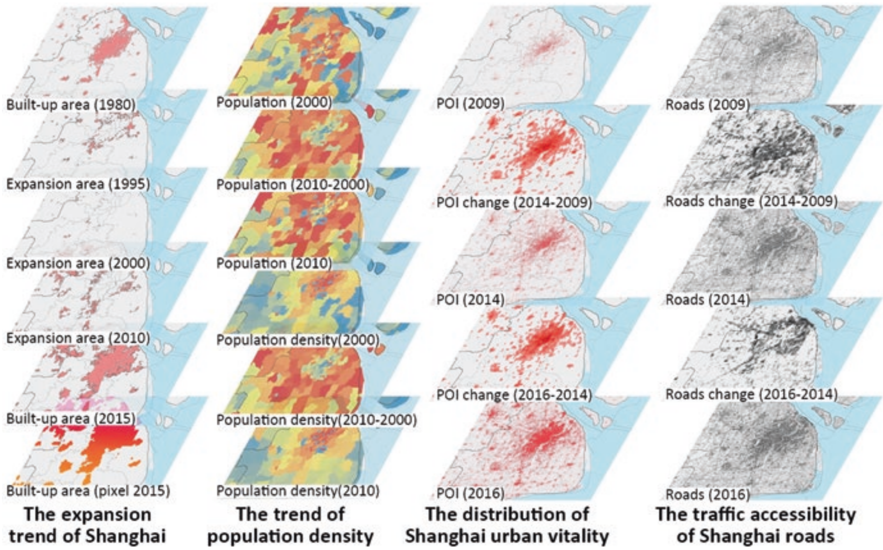

Fig. 5.3 Historical data analysis: changes in Shanghai's urban form and function development

traffic using the regional road network and public transportation data, and clarified the accessibility level of the area where the site is located. At the same time, comparative analysis of the trend of accessibility in the past decade and the possibility of changing regional accessibility and viability by cross-correlation of POI data was carried out. We found that adding branches is an effective way to improve traffic congestion and improve accessibility, which can be applied to our design strategies.

In addition to the objective perspective, we also conducted social data analysis to subjectively explore the modern meaning of the cultural value of silos. Using the Weibo (Chinese version of Twitter) keyword related to silo, we obtained the most frequently appearing vocabulary (Fig. 5.4), which is centered around fashion culture, artistic charm, civic life, and historical relics. These keywords portray the modern image or the identity of silos in the minds of Shanghai residents, which is a unique cultural landmark born with history and future. Where the silo is transformed to an art museum with the impression of artistic charm, the second word "art" is also considered in our design.

Fig. 5.4 Social data analysis: real-time frequency of Weibo keyword search

5.3.2 *Citizens: Microanalysis for Refined Site Design*

The design principle of regarding the local residents as the main users of the site led us to conduct a series of analyses that mainly focus on the public service facilities, including the vitality of the facilities, the accessibility of the public service facilities, the matching degree of the public service facilities, and so on. The last word, “life,” expresses the thinking about the people-centered design and the future usage pattern of the silo area reflected in the time dimension.

Through the site and surrounding road network and public transportation data, we identified the current high accessibility area of the site and cross-validated it by using POI data. Then, we observed changes in POI data and road networks to find the development trends. The result shows that mixed use was initially achieved within the site, and road density along the river increased significantly (Fig. 5.5). However, we found that the public services around the site are insufficient, which is reflected in the uneven distribution of public facilities, poor accessibility of public facilities, and lack of diverse, convenient, and complete service facilities (Fig. 5.6). For example, there are few sports facilities in the venue. It is advisable to increase playable areas for local residents and tourists to exercise. Even though there are many scenic spots in the southeast region of the site, they are not well connected with the Minsheng Wharf. To strengthen the connection between the two sides of the riverbank and enhance the attractions of the site, an elevated view site and ship docking point can be set up along the riverbank.

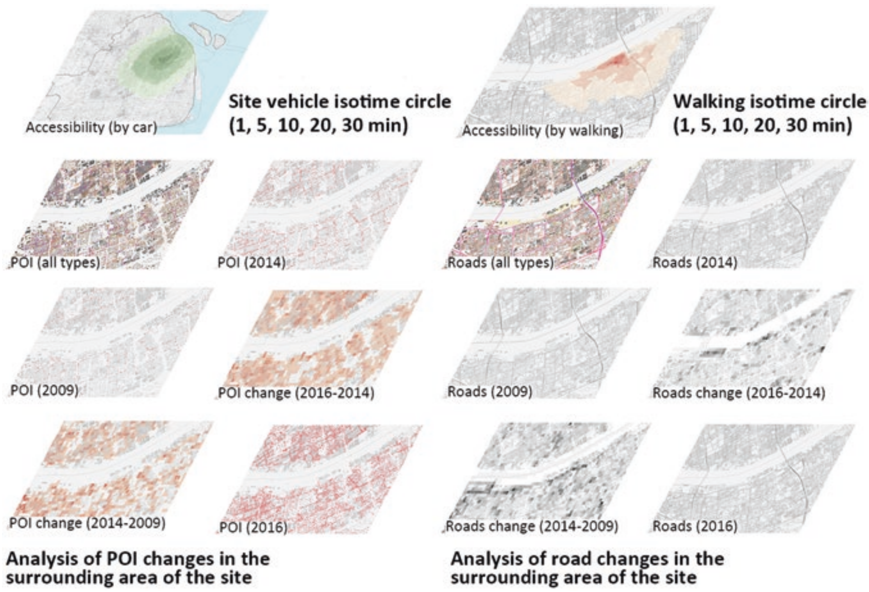

Fig. 5.5 Analysis of accessibility and function around the site

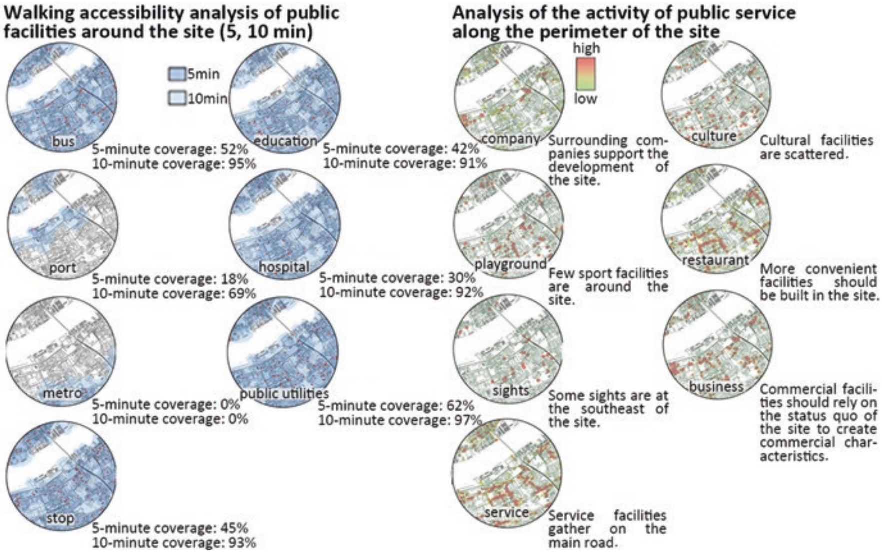

Fig. 5.6 Site analysis of public service and vitality

5.3.3 Case Study: Multiple Comparison for Better Understanding and Designing the Site

In the Shanghai 2035 Plan, Shanghai set very high expectations for its waterfront space, making the construction and renovation of the two sides of the Huangpu River become a very important issue. The Shanghai City Space Art Season also provides an important opportunity. As analyzed above, we aimed to make the best use of existing advantages and enhance the identity of art. Through the construction of artistic and cultural nodes, the overall space quality and artistic vitality of the waterfront area will be enhanced, and the radiation and service effects of the waterfront area on the surrounding urban areas can also be strengthened.

On this basis, we studied cases from world-class art and culture waterfront space, and summarized the outstanding experience from the cases. We selected the Tate Gallery area along the River Thames in London, the Exhibition Centre area at Sydney’s Darling Port, and the Orsay Museum area on the Seine River in Paris as our cases. The urban texture, the urban mixing degree of land use, the urban vitality, and the walking environment in these case areas were analyzed (Fig. 5.7). Compared with the cases above, we found that the cultural influence, the art, and the publicity of the waterfront space need to be promoted in the 80,000-ton silo area.

5.3.4 *Color Analysis of Building Facades along the Perimeter of the Site*

Color as a significant symbol of a city image was also analyzed in our research (Fig. 5.8). Colors of the 80,000-ton silo and surrounding areas were extracted by collecting pictures from facades of various buildings, in which the color and brightness of buildings in different historical stages were key elements. The differences in color performance of various buildings in various periods can be used as an important reference for the color planning of urban architecture. The result shows that colors in this area are scattered, in which historical industrial buildings of the twentieth century are characterized by low saturation and low brightness with a red-orange or gray color, while the appearance of modern commercial buildings has more color brightness, and the hue is more complicated. Referring to our analysis, the improvement and design need to be more complete, conforming to the trend of development.

In general, the multidimensional data-based city images help us better understand the physical environment and urban activities. According to our analysis, our design concept is that the 80,000-ton silo should not be just a closed, point space for elegant cultural exhibitions, but remain consistent with the rich historical and cultural value of the whole Minsheng Wharf area, which is, from both space and time perspectives, a magnified "city exhibition" where all residents and visitors enjoy themselves.

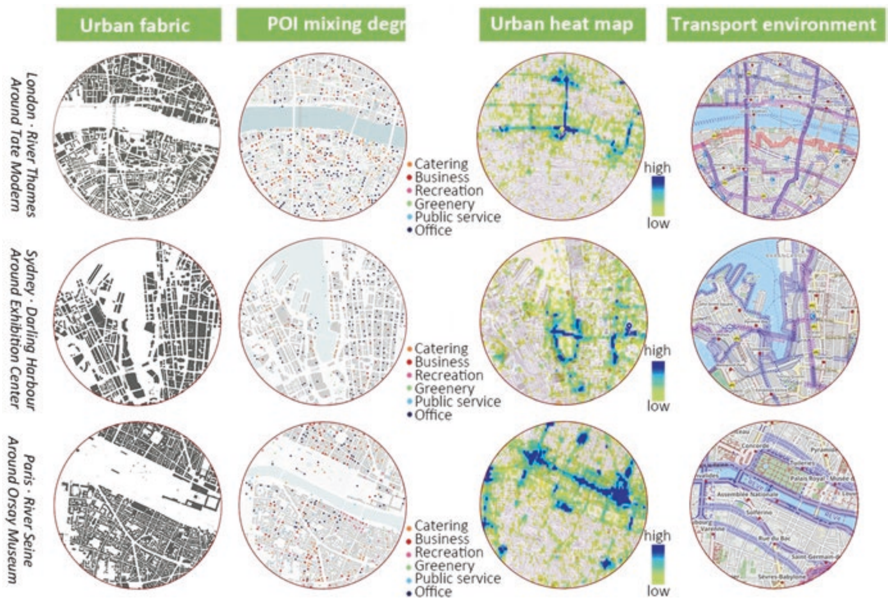

Fig. 5.7 International case comparison: world-class art culture waterfront space

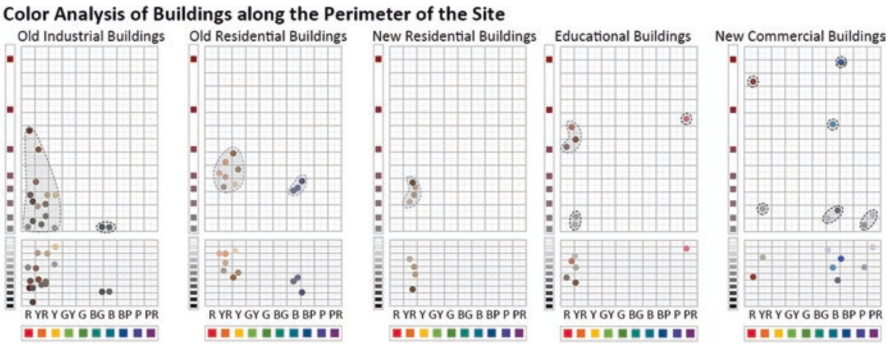

Fig. 5.8 Architectural color analysis of Shanghai

5.4 Design Proposal: Data, Identity, and Strategies

Based on the analysis above, we ultimately defined three words, "memory, art, and life," as the fundamental motif of this design. The first word, "memory," represents the rich historical memory of the 80,000-ton silo area. It has the industrial characteristics of Shanghai in the historical industrial relics of the same age as the Lingyi and Linger residential districts. The imprint of the development of Pudong represented by the old community and emerging high-end residential buildings is also a vital element of memory. The second word, "art," implies the future development orientation of the 80,000-ton silo area, which means using culture and art as carriers to activate the entire area. What is expressed in the third word "life" is the future of the silo area from the time perspective. We hope that the silo can perform as a curtain in the daily life for local residents and host a variety of events and activities in the future. In our imagination, expressed in these three words, this area will eventually be an exhibition that never ends (Fig. 5.9).

5.4.1 Rebuilding Cultural Identity

To achieve the goal of "memory, art, and life," a core issue is that the cultural influence of the 80,000-ton silo needs to be enhanced. Through the real-time activity analysis of people and distribution of Shanghai's cultural facilities, we found that the 80,000-ton silo area lacks vitality and has a weak cultural drive around the site. Therefore, we proposed an urban construction system with the main goal of excavating, activating, and enhancing urban cultural connotations. Based on the original culture, it will combine existing cultural elements with the characteristics of the times, and apply innovative technology to improve the individual experience of urban culture. It reflects the design spirit of fine-scale, local perspective, and innovative ways.

Fig. 5.9 Logo and motif for this design

The corresponding strategy is reinventing the cultural identity of the silo. Cultural landmarks include the entire Minsheng Wharf and the ferry that best reflects the lifestyle of the two banks of the Huangpu River. Specially, three steps should be carried out. The first is the transformation of the old silo. The second is the reuse of the equipment and the improvement of the ferry landscape to activate the vitality of cultural nodes. Moreover, we also focused on improving the entrance space of these cultural nodes and the open green spaces along the coast to enhance its consistency.

5.4.2 Making Open-space Oriented Waterfront Space

The existing waterfront space and the surrounding area are boring and have a single function, lacking activities such as business, entertainment, and culture. Therefore, we aim to make it an open-space oriented waterfront space based on characteristics of urban residential activities to meet various needs of people and provide a flexible, open, and diverse urban space.

The corresponding strategy is to make the waterfront space more open and interesting. The reconstruction of cultural identity should be coordinated with the overall image of the city. Based on the color analysis of architecture in Shanghai, we designed the site with more friendly building facades. In view of the spatial problems existing in the area, we connected the waterfront space and the city hinterland through the comprehensive opening of the inner courtyard of the Minsheng Wharf and the construction of the open landscape skeleton.

5.4.3 Reshaping Cultural Relics as Daily Places

There are no conventional exhibitions in silos, which makes the absence of regular activity support in public cultural spaces a major problem. We put forward the four-dimensional view of urban design, which emphasizes event making in urban design. The rise of data science has enabled planners to study the effects of sporadic events on urban space in addition to the design in the three-dimensional space and consider the influence of accidental events taking place in urban spaces. We attempted to combine the needs of "moment" in daily activities with the three-dimensional consideration of the original space to reshape cultural relics.

The corresponding strategy is creating cultural events and moments in old buildings. Cultural landmarks should not only be commemorative but also become rituals and celebrations of everyday life. The first step is to establish an intimate connection between the waterfront and the inner area through the revitalization of the flexible reserved land and the internal capillary, so that the culture of the Minsheng Wharf is an active part of the rich daily life of the lot. Then, we reshaped the interface and walking environment of several north-south branches in the area, and appropriately opened the closed residential quarters, infiltrating the pleasant streetscape into the living environment and making the public space skeleton a link connecting collective life skills and personal cultural identity. Finally, the street corner space was formed as a place that includes commercial services, daily rest, and spontaneous cultural activities.

5.4.4 Creating Daily Oriented Cultural Moments

To bridge the gap between upper-level planning and needs of local residents, we designed the culture to be more involved with daily life. The design seeks to enhance the urban culture and urban space without losing the justice of urban space. Combined with the traditional urban space and the emerging data technology, the urban culture and its space entity were integrated into the daily life of residents.

The corresponding strategy enhances the connection between daily used space and cultural landmarks. The rebuilding of cultural identity is not only the display waterfront of architectural noumenon but also the performance of urban cultural life. The node of the landscape skeleton between the waterfront and the hinterland is a potential space to accommodate a series of activities and events related to waterfront cultural nodes. For example, we combined the squares outside the silo with the expressive facade of the building to form a light and shadow show and outdoor exhibition. We also built the waterfront space in the north of Miaopu Road into a commemorative and casual outdoor theater under the tower crane. Moreover, we used the intersection of the landscape road and the subway station to form a corner space that accommodates commercial leisure and creative markets.

5.4.5 Modeling and Adjusting the Master Plan

To predict and simulate the future usage scenarios and obtain real-time feedback towards our planning and design, we carried out simulations for some detailed aspects such as pedestrian flow and microcirculatory climate (like temperature, humidity, wind speed, MRT, etc.). According to the results, it is necessary to further increase the open space, such as the green space and waterfront area, in the site to reduce the space temperature inside the block and adjust the local microenvironment. Then, the newly designed area on the east side of the site should be designed with soft paving and permeable floors to control the volume of rain. Moreover, the enclosed layout can decrease the wind speed, thus creating a more comfortable outdoor space inside every single group. Finally, the proper blocking effect of the building allows the open space around buildings to have the best average radiant temperature (Fig. 5.10).

By rebuilding culture identity, making open-space oriented cultural moments, reshaping cultural relics as daily place, and creating daily oriented cultural moments, more green corridors, interesting nodes, and coordinated public space were designed. According to the results of the simulations, these strategies help to generate the master plan, which is shown in Figs. 5.11 and 5.12.

5.5 Detail Design

5.5.1 Mode of Renovation: Connecting the Waterfront and Surrounding Communities

The full connection between the site and other areas of the city is vital to develop the site. The urban influence of silos and the Minsheng Wharf area will spread through the connection along the whole waterfront, especially the interaction with the landscape belts in the other side of the Pudong District. The former has been well implemented, while the latter will be achieved through projects such as the Minsheng Road Landscape Transformation, Yangpu Bridge Industrial Park Revival, and Yangjingbang Riverfront Space Construction. Important nodes such as waterfront factories, old warehouses under the Yangpu Bridge, subway stations, and

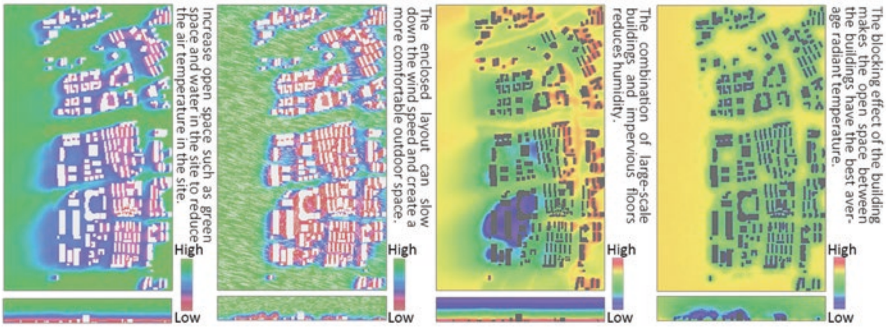

Fig. 5.10 Results of simulations

Fig. 5.11 The layout of the master plan

office buildings should be linked by trunk roads. In addition, urban cultural nodes should also be linked with surrounding communities by some walkable streets. Because of the complicated conditions of the site, the street space and property rights boundary should be defined. Then, some positive actions can be conducted to activate the space and manifest the culture of the waterfront, such as reconstructing

Fig. 5.12 The aerial view of the master plan

the interface of buildings, introducing community activities, and making some transition zones for pleasant visiting.

By simulating different scenarios, we designed a series of modes and strategies for renovation, some of which are shown as follows. Mode 1: in order to present the features of the ferry along the Huangpu River, we fully utilized the abandoned ferry and put it across the road, using the vivid coastlines to revisualize the ritual atmosphere. Mode 2: we opened the waterfront by some paths to old factories to bridge the gap between the old factories and the riverbank. The factory yard is no longer blocked from the bank but can be shared for all kinds of outdoor cultural fairs. In addition, the 80,000-ton silos and other factory buildings as cultural relics can also be shared. Mode 3: walls along the street are replaced by shops, green belts, and small public space. The vivid street life was revitalized as a link between the cultural Huangpu River Bank and surrounding traditional residential areas.

5.5.2 A Case for Creating Cultural Moments

We may take the reconstruction of the square outside the Changyi Road subway station, which is designed as a node of community activities and public art space, as an example of creating cultural moments. This is the node between Minsheng Road and the Changyi Road Subway Station. We created a series of designs to handle complex streamlines of walkers and bicyclists and to increase public activities by providing public space for citizens. Specifically, we designed a sunken plaza to contain flows from subway entrances, increase bicycle corridors for cycling, and make some spaces for people to relax. We also encourage art activities that are more

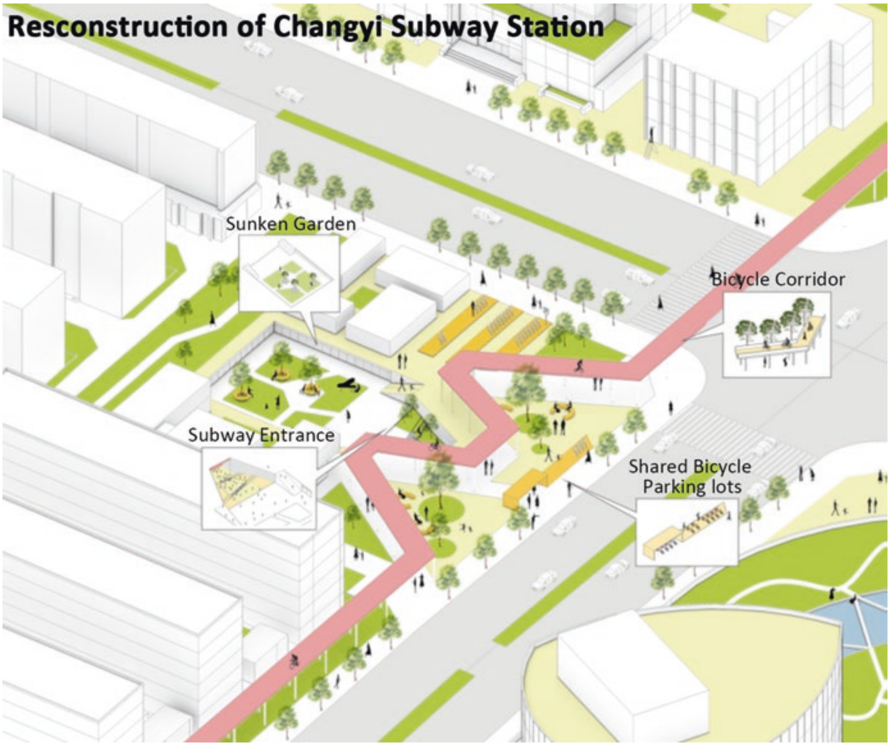

Fig. 5.13 The design scenario for the corner space

community-oriented, such as community artist exhibitions, creative markets, and children's art workshops (Fig. 5.13).

5.6 Conclusion and Discussion

This is a typical case of using multidimensional data to abstract city images. We used Data Augmented Design as the research method and integrated various sources of data, including traditional statistics, GIS data, and social network data, with the whole process of design such as preanalysis, design concept, detailed strategies, and specific design schemes as well as modeling and adjusting. The aim of this research-design framework was to produce a more rational, scientific, scalable, and modifiable urban design program.

By combining both traditional and emerging data, this design selected three key words, "memory, art, and life," to depict the design concept. This design echoes Shanghai's goal of creating a "global city of excellence" and the competition theme of "openness, sharing, and innovation." It aimed to make the 80,000-ton silo industrial heritage area in Shanghai a people-oriented "world-class waterfront art district." The restoration and protection work of the industrial heritage is expected to gain new value in the new era based on its historical value. According to the analysis of the subjective sentiment of citizens, we chose to add more art elements into the performance of existing cultural relics to activate this site. In addition, we are concerned about the needs of the surrounding residents and other Shanghai citizens, so we connected the waterfront space with the communities and created more cultural moments for people. At the same time, the historical and cultural memories were excavated, and various scenarios for the public open space were proposed.

However, there remain several limitations in this design. First, we chose only three cases of excellent urban sites to conduct case studies, and factors of concern were limited to urban texture, the urban mixing degree of land use, urban vitality, and the walking environment. More cases and more factors need to be involved. Second, urban vitality was initially measured by the degree of crowd gathering, thus guiding the structure and location of public space. However, it is hard to distinguish local people from visitors; as a result, more detailed habits and customs of different people are impossible to identify. Third, the design still depends on spatial intervention, while technologies and digital solutions are not considered enough.

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Chapter 6
Fine-Scale Recognition-Based Design Guidelines for Dealing with Shrinking Cities: A Case Study of Hegang

Abstract Shrinking cities as a phenomenon expanding rapidly in the world have aroused great interest in China in recent years. Hegang is a city in the northeast China, which has been losing its population and almost finished depleting the existing mineral resources, accompanied by the surplus of land and buildings, and the decline in the quality of space. This chapter applies Data Augmented Design (DAD) in shrinking cities, aiming to search for solutions to these problems in a low-cost, operational, and resilient way. Based on the principle of actively responding to the urban shrinkage, this chapter embraces multisource data and methods in DAD to put forward a four-step research framework. First, we identify and analyze some national strategies that could be used to address problems in shrinking cities. Second, we identify some potential areas for design at the block scale and some abandoned buildings. Third, we divide these elements into different types according to five standards. Finally, to address existing problems, fine-scale design guidelines are proposed for different types of design elements. These guidelines are highly implementable and have been recognized and appreciated by planners from the local planning institute.

Keywords New data environment · Shrinking city · Design guideline · Urban design · China

6.1 Introduction

Cities for which development was based on a single industry or on the concentration of activity in a single sector (Friedrichs 1993; Bontje 2004; Lang 2005) have been affected by a series of globalization processes and are adversely affected by population decline (Martinez-Fernandez et al. 2012). Indeed, cities have been expanding rapidly around the world for decades, especially in developed countries. In China, however, many cities, especially those in northeast China such as Hegang, are growing slowly or declining. They developed rapidly in the early industrialization period

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by heavily relying on a single industry. Due the process of globalization and resource exhaustion, urban shrinkage is gradually appearing in these cities. Researchers found that these shrinking cities shared common elements of what can be characterized as a "shrinkage identity" (Reckien and Martinez-Fernandez 2011). Martinez-Fernandez et al. (2012) defined a "shrinking city" as an urban area—a city, part of a city, an entire metropolitan area, or a town—that has experienced population decline, an economic downturn, employment decline, and social problems as symptoms of a structural crisis.

Studies about shrinking cities have mainly concentrated on the definition (Häussermann and Siebel, 1988), identification (Bontje 2004; Schetke and Haase 2008; Long et al. 2015), classification (Alves et al. 2016), causes and mechanisms (Martinez-Fernandez et al. 2012), and comprehensive research methodologies (Hoekveld 2012; Haase et al. 2014; Lauf et al. 2012; Haase et al. 2012). Although there are some discussions on urban planning strategies that could be used by shrinking cities, they have mainly focused on the contexts of North America and Europe. There is little empirical research and few practices that have addressed the shrinkage of a certain region or city in China (He et al. 2018; Du et al. 2018).

In this context, the Shrinking City Research Network of China (SCRNC) organized a shrinking city workshop in China with Hegang as the research and design object to explore strategies and urban designs that can address shrinking cities in China. This chapter describes one work that was developed in this workshop and proposes some flexible design guidelines for Hegang based on the DAD (data augmented design) method. Following this section, we introduce the methodology, including the design site and research framework. Then, we interpret this framework in a more detailed way and propose some design guidelines. The last section concludes and discusses the academic contributions and potential applications of this work as well as future research directions.

6.2 Methodology

6.2.1 Design Site

In this chapter, the study area is Hegang, which used to be one of the most important coal production cities in northeast China (Fig. 6.1). In 2011, it was designated as one of the third batches of 25 "resource-exhausted" cities. Due to the decline of the coal mining industry, Hegang gradually lost 1/3 of its population. Moreover, because Hegang is a traffic terminal, it can hardly transform to a tourism city. In the short term, there is little probability of a population increase. Similar to most shrinking cities, in Hegang, there is a large amount of unused space, mainly due to the continuous decreasing population and increasing construction. What follows is the destruction of the ecological environment and a decline in the quality of the built environment. For example, the discontinued mining area Linbei is a scene of decay because the land is exposed and appears to be bare, with vacant built areas full of waste (Fig. 6.2).

Fig. 6.1 The location of the design site

Fig. 6.2 The destruction of the ecological environment and the decline in the quality of the built environment in Hegang. (**a**) Mine expose. (**b**) Urban space disorder

Fig. 6.3 Some positive actions that can address spatial disorder. (**a**) Buildings for settlement. (**b**) Urban parks. (**c**) Public parking. (**d**) Ecological restoration

To solve the problem of spatial disorder, the Hegang City Planning Bureau has adopted some effective strategies (Fig. 6.3). For abandoned mines, an Ecorepair strategy has been adopted that involves a low-cost, local, and natural design. Shanty towns in the city have been demolished, and vacant land has been transformed into urban parks, parking lots, and public squares.

Considering the discussion above, we focus on serving existing urban residents by fully learning from local positive actions and international experiences and improving the quality of the existing space and the lives of local residents. Given the level of local economic development, we are attempting to develop a low-cost, operational, and flexible design. In summary, this chapter proposes some guidelines for solving the spatial problems of Hegang in a low-cost, operational, and resilient way.

6.2.2 Research Framework

To achieve the aforementioned goals, a four-step analysis is proposed in this chapter (Fig. 6.4). First, we identify and analyze some national strategies that could be used to address problems in shrinking cities. By considering these strategies along with China's relevant policies and the development characteristics of Hegang, we clarify our design objectives. Second, to better understand and use the abandoned urban space, we identify some potential areas for design at the block scale, including green spaces, vacant land, shanty towns, mines and river bank, and some abandoned buildings by using updated satellite images and self-collected pictures. Then, we

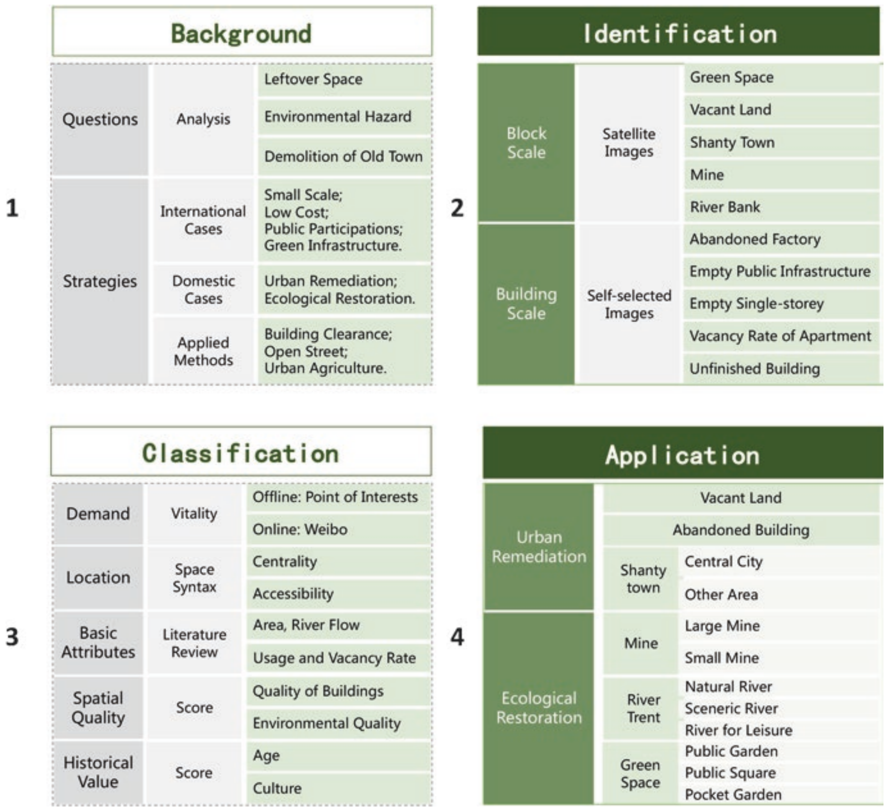

Fig. 6.4 Framework of the four-step analysis

divide these elements into different types according to their locations, basic attributes, and historical value, as well as the quality of the surrounding space and local residents' activities. Finally, to address the existing problems, fine-scale design guidelines are proposed for different types of design elements.

6.3 Case Study

In the early days, under the guidance of traditional growth-oriented development, the plan for shrinking cities and regions focused on "regrowth." National and local governments considered the economic recessions and population decline caused by urban shrinkage to be temporary fluctuations. They attempted to change this "temporary" unfavorable situation through some investment or fiscal policies (Verwest 2011). Since the beginning of the twentieth century, most industrialized countries, headed by the USA, have continued to maintain traditional growth values in terms of urban development. With the deepening of shrinking city research conducted by academia and policy makers, an increasing number of countries and local governments have begun to better understand shrinkage, and thus, planning strategies based on rational and streamlined goals are being formulated. Urban development is no longer based on the premise of economic growth through investment, and development targets no longer involve increasing the number of people and creating larger built-up areas. Instead, focus is placed on cities' stock of space, sustainable development, and ensuring the quality of life of residents and the vitality of urban centers. Due to the diversity of the subjects, elements, and processes of shrinking cities, the methods used to address shrinkage often involve a collection of different policies (Lauf et al. 2012) and some spatial solutions. This chapter, however, specifically focuses on the spatial design of shrinking cities.

In terms of urban design, there are four main initiatives (Fig. 6.5). The first is to deal with vacant land and buildings. Urban shrinkage often leads to a large amount of vacant land and a large number of vacant buildings, which have a negative impact on the landscape and urban security. Therefore, one of the key issues in dealing with shrinking cities is to address open spaces and vacant buildings. Philadelphia's Green Plan in 1974, Buffalo's Queen's City Master Plan in 2006, and Detroit's Vacant Property Campaign in 2008 all provided solutions that addressed vacant land and

Fig. 6.5 Four main urban design strategies used for shrinking cities. (**a**) Updated old buildings. (**b**) Green infrastructure. (**c**) Art involvement. (**d**) Urban agriculture

buildings. Second, developing green infrastructure is a commonly used and effective way to respond to shrinking cities. Schilling (2008) proposed green infrastructure in the framework of the rightsizing model and claimed it could be employed to rebuild America's shrinking cities. In this model, some vacant buildings and sites will become temporary or permanent community gardens, pocket parking lots, urban farms, and community forests. This model aims to realize the sustainable development of the city while restoring urban productivity. Third, some public participation methods have been introduced to help revive public spaces. The involvement of art in community and urban agriculture is vital for shaping the city and civic life. The shrinking town of Lyons, Nebraska, USA, reused abandoned stores to reshape street vibrancy and community cohesion, and artist Matthew Mazzotta worked with local community residents to design and build a small theater. This small-scale community public space has brought about real changes for the local residents of this shrinking town. Last but not least, urban agriculture is an economic and natural way to encourage public participation. In the small town of Todmorden, West Yorkshire, England, the founder of the Incredible Edible project, Pam, with a group of volunteers grows fruits and vegetables in all corners of the town. Once the fruits and vegetables are ripe, they are free for residents and tourists. Currently, there are more than 30 towns in the UK that are replicating the Todmorden model.

To conclude, there are four key aspects of these four initiatives; they are small-scale and low-cost initiatives that involve public participation and green infrastructure. The first aspect, small scale, makes sure the action is feasible and maximizes the use of limited resources. The second aspect, low cost, is necessary due to the limited economic development of shrinking cities; thus, it is better to implement a low-cost design. Public participation as an important aspect of the design that plays a more prominent role in shrinking cities. In shrinking cities, public participation not only leads to the conservation of resources but also promotes community cohesion and improves the quality of life. Green infrastructure can be developed to address vacant land and is suitable for locale that desires to implement "global" designs. These four key aspects are utilized in our design strategy developed for Hegang.

6.4 Fine-Scale Identification of Spatial Elements and Human Activities

Fine-scale spatial elements are the foundation of designs developed for shrinking cities. Spatial information such as data on land use, street networks and human activities such as path selection and crowd aggregation are essential for design.

In terms of land use, there are many vacant plots, such as abandoned factories, shanty towns, and shutdown mines, which are typical of lost space and inefficient land use in cities. In this chapter, we use remote sensing images to identify changes in the shanty towns from 2011 to 2019 and six current types of land use, including

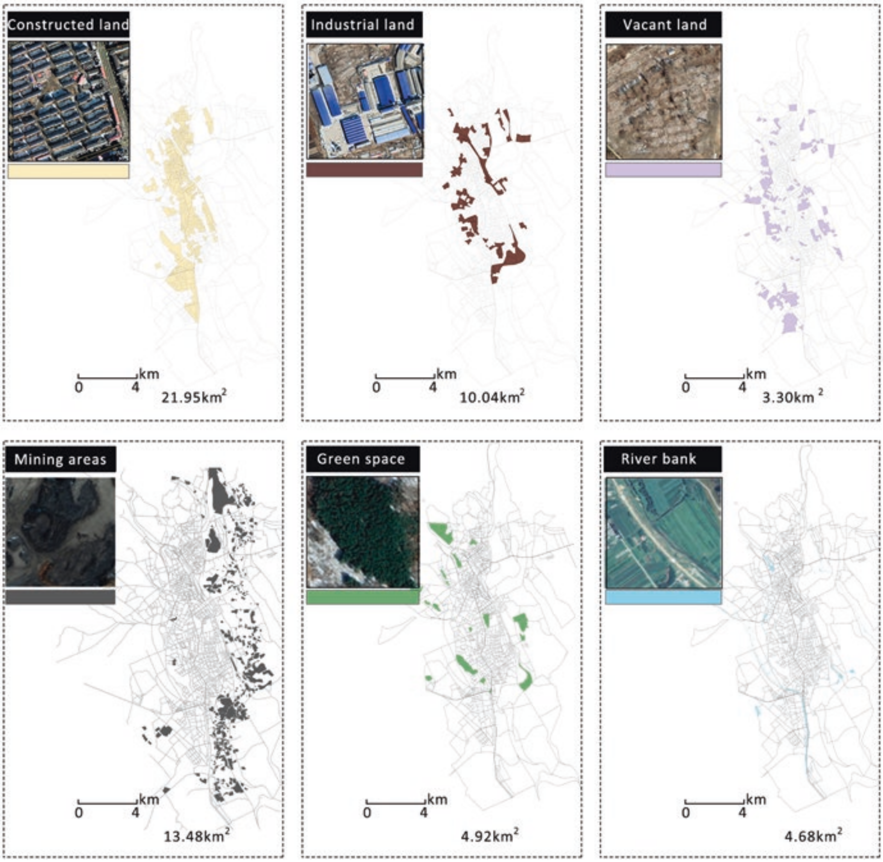

Fig. 6.6 Six types of land use identified by remote sensing images

construction land, industrial land, vacant land, mines, green space, and rivers (Fig. 6.6). The results show that the large shanty towns have been removed, and in the last decade, many new buildings have been constructed for the resettlement of local persons. Due to the population, there is excess demand for construction land. Factories have been abandoned, and there is a large surplus of vacant land. The data show that nearly 30% of construction land should be used for other purposes. This excess land could serve new functions, which would increase its value and improve urban vitality in the city.

Open data and big data are vital for understanding human activities, such as changes in lifestyles, and managing the new lives of the citizens (Shen and Li 2017). In this chapter, we reveal the pattern of human activities in three steps. First, we use the spatial syntax method to identify the center and axis of the city as well as the main roads. The results are consistent with the actual situation we observed (Fig. 6.7). Then, we use POI (point of interest) data to identify the distribution of

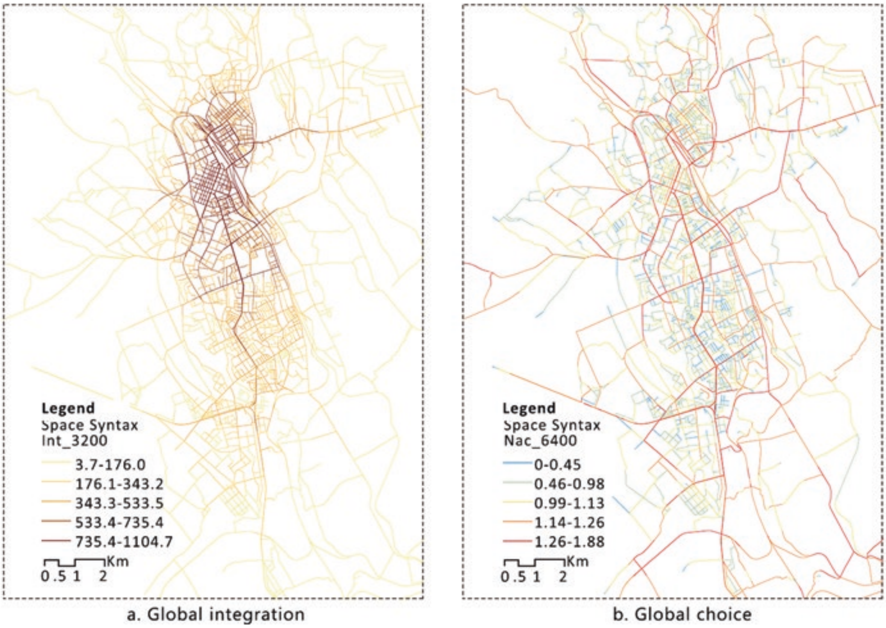

Fig. 6.7 The result of spatial syntax analysis. (**a**) Global integration. (**b**) Global choice

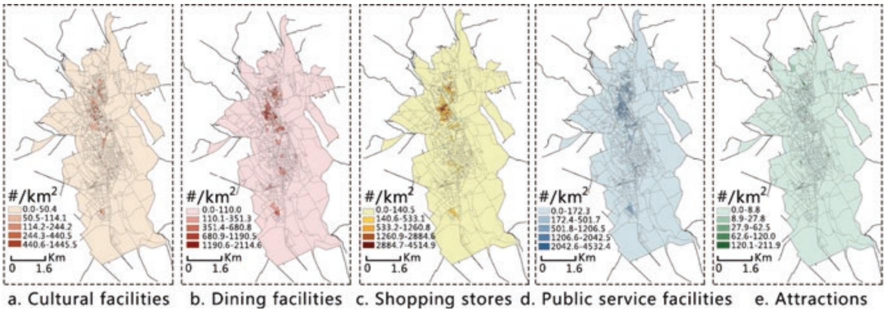

Fig. 6.8 Distributions of various facilities identified by POI data. (**a**) Cultural facilities. (**b**) Dining facilities. (**c**) Shopping stores. (**d**) Public service facilities. (**e**) Attractions

various facilities, including cultural, dining, shopping, and public service facilities and attractions, across the city. These facilities provide essential support for the usage of vacant lands (Fig. 6.8). Finally, we apply data from social media network data and mobile phone data to understand the real usage of urban space. The results are shown in Fig. 6.9. Baidu Eye data generated from Baidu Map (the Chinese version of Google) can be used to illustrate the distribution of Baidu users, which can almost be seen as uniform sampling within a city. The distribution of Weibo (the Chinese version of Twitter) data can be used to show where young people are active in the city.

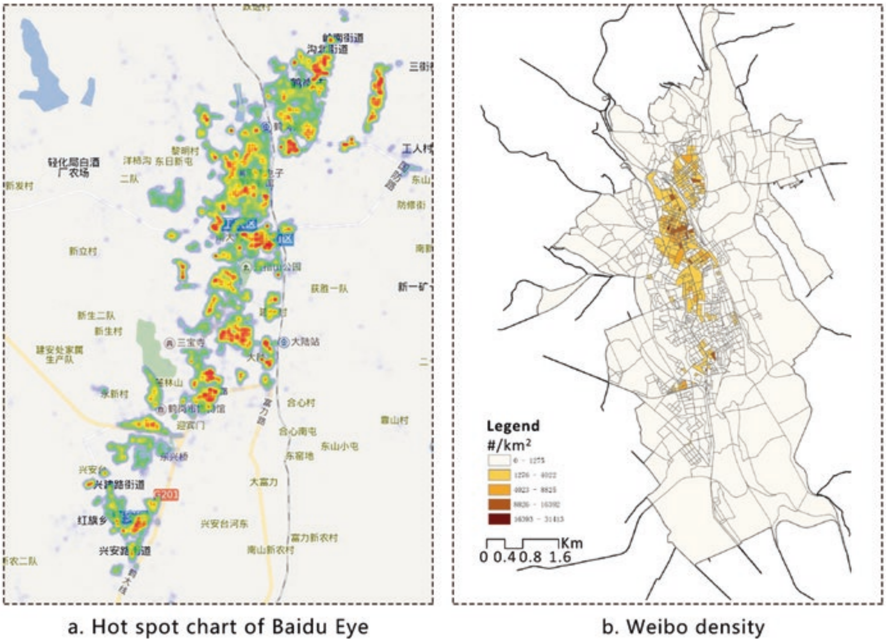

Fig. 6.9 The distribution of Baidu Eye (left) and Weibo (right). (**a**) Hot spot chart of Baidu Eye. (**b**) Weibo density

6.5 Design Guidelines for Different Types of Elements

On the basis of the results of the fine-scale identification process, we divide the design elements into different types and develop corresponding guidelines. Five factors are selected as the basis of the classification: people's demand, the location, the basic attributes, spatial quality, and historical value. We apply the concept of "Urban Remediation and Ecological Restoration," which was proposed by the Central Urban Work Conference of China in 2015, to our design guidelines to achieve our goal of serving local people.

Urban remediation involves taking action to renew cities to promote the quality of life and happiness of the residents of the city and make communities livable. In view of this, we focus on three main elements: vacant buildings, vacant land, and shanty towns. The vacant buildings can be divided according to their functions into apartments, industrial buildings, and public buildings. In terms of location, quality and historical value, each type of building can be classified into a demolition type and renewal type (Fig. 6.10). Some low-quality buildings with little historical value that are located at the edge of the city should be demolished. Others should be reshaped using different strategies. For example, some vacant apartments could be transformed to public spaces used for communication and recreation. Workshops could be created to help young people to start low-cost businesses in some of the

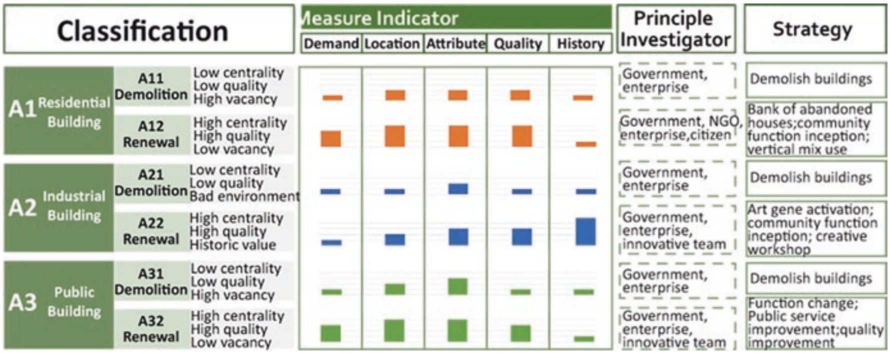

Fig. 6.10 Guidelines for vacant buildings

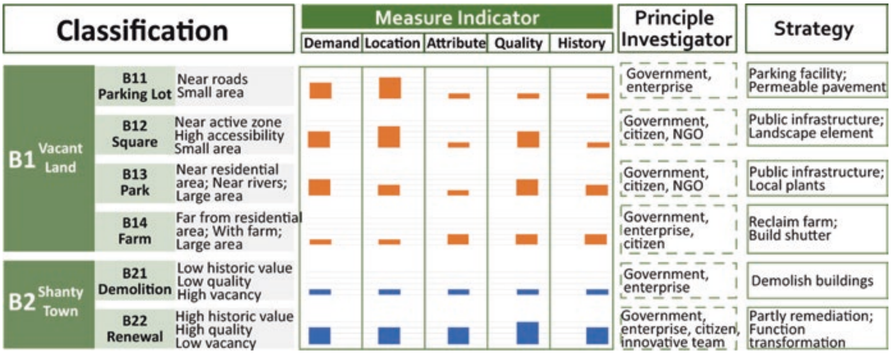

Fig. 6.11 Guidelines for vacant land and shanty towns

good-quality industrial buildings in the central city. In addition, public buildings such as abandoned commercial buildings can be used for community functions such as activity centers for elderly people or kindergartens.

Vacant land is mainly consistent with local activity and designed for public use; for instance, it can be used for parks, parking lots, a public square, or urban farmland and equipped with related facilities. Most of the shanty towns have been removed, and the areas have been reshaped as vacant land. A few of the better quality, historic buildings have been retained as urban memory areas (Fig. 6.11). The public and social organizations are more involved in these two aspects of urban remediation.

In addition to urban remediation, ecological restoration is another theme. The main strategies are divided into three categories, namely ecological restoration, river management, and landscape improvement (Fig. 6.12). According to their size, mining areas can be classified into small and large areas. The former could be used for garbage backfilling or designed for special landscapes. According to George Wade Energy Hill, solar or wind power could be planted on the slopes of the mines

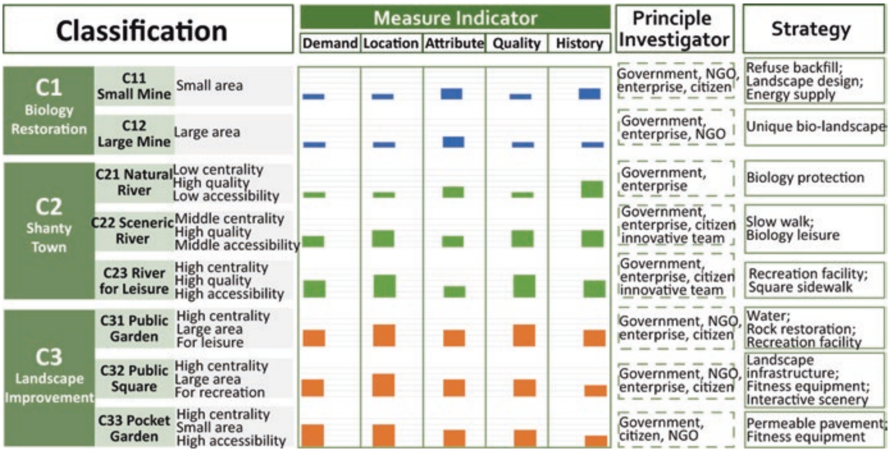

Fig. 6.12 Guidelines for ecological restoration

and used to power surrounding homes. The large coal mining areas could be retained in a ecological restoration way, or designed to unique ecological landscape. The second category, rivers, can be divided according to their locations and the surrounding environment quality into wild rivers, scenic rivers, and leisure rivers. Wild rivers are rivers far located from the central city and can be treated as ecological barriers with little artificial environment. Therefore, river dredging and planting vegetation around the channels are particularly important for wild rivers. Scenic rivers are those that have beautiful scenes and are close to residential areas, where some walking trails should be built to provide good conditions for tourists. Leisure rivers, which are near the central city and have good quality, can be designed as small parks and equipped with some public facilities. The third category is public activity areas, which mainly includes public parks, civic squares, pocket parks, and systematic urban parks; these should be constructed and equipped with appropriate facilities. The public should be encouraged to participate in the process of landscape improvement.

6.6 Conclusions and Discussion

In this chapter, we fully embrace the methodology of DAD to understand the design site and identify existing problems. As is done for international cases, this chapter emphasizes the use and transformation of vacant land and buildings. The new data environment that combines both remote sensing images and mobile phone signal data is helpful for identifying vacant land at the city scale. It is worth mentioning that, as noted in this chapter, we fully consider relevant local actions and international in the process of developing suitable guidelines for the designs. For example, green infrastructure has been used in international cases and is suitable for China's shrinking cities because it can be used to maintain the ecological environment and convert low-quality areas into better-quality ones in a low-cost way. Green infrastructure is regarded as the reserved land of the city. If land is needed for future development, these areas can be redeveloped. We fully consider local actions when converting vacant land into parks, parking lots, and public squares. The areas far from the city center will be used as agricultural land to develop the first industry.

Unlike other countries, in China, residential buildings are mainly multistory buildings. As a result, the vacant parts of multistory buildings are a great problem when dealing with vacant buildings. The buildings in the shanty towns are mainly single-story buildings. Due to China's polices for these areas, the central government of China has invested a large amount of money to improve the quality of life for people who live in these areas. Therefore, it is easy to deal with these buildings. However, many households live in a multistory building, and it is more difficult to deal with vacant rooms than vacant buildings. Vacant buildings can be managed by the government as a public service, and they can be used to provide more places for neighbors to gather, while the ownership of the buildings remains unchanged.

Hegang has a large amount of land surface that was used for open-pit mines that were abandoned after the resources were exhausted. The potential threats of soil erosion and environmental deterioration exist in these mine areas. However, these mines provide opportunities for special landscapes and ecological restoration. This chapter proposes some rational methods for utilizing the mines, namely for waste backfilling, energy supply, and special landscapes. These strategies not only help to solve the problem of ecological environmental damage in Hegang but also fully respond to the concept of "Urban Remediation and Ecological Restoration" in China.

As a result, the research framework and guidelines of urban design provided here have been approved and supported by the local planning institute and relevant urban researchers. Nevertheless, there is still some potential bias, which can be addressed in future studies. First, the method of using mobile phone data to distinguish building vacancies needs further verification. Second, although this chapter has quantitatively studied urban vacant land, it lacks the quantitative measurement of urban spatial quality, which is important because the quality of urban space will also affect the adjustment of urban land use. Third, the design guidelines proposed in this chapter only act as examples, and the specific implements and effects need further research and confirmation.

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Part III
Learning from Other Cases to Better Design Sites

Chapter 7
Quantifying Urban Form as a Case Study in Expansion-Oriented Design: Design Practices in the Tongzhou Subcenter

Abstract As one of the essential parts in urban design practice, the methodology about case study meets new opportunities in the new data environment. Quantitative research framework aiming at rational and effective case study is the second type of Data Augmented Design (DAD), which is applicable to expansion-oriented design. The specific framework is constructed over four steps: The first step is the analysis of the built environment of case cities and the extraction of the spatial indicators in every spatial category; the second step is to quantify these indicators and abstract them into the spatial form modes that are considered urban genes; the third step is to select suitable urban genes in each urban gene bank, combine them into the planning project and adjust them flexibly according to the local conditions; finally, after the design project, the study evaluates the indicators of the built environment in the planned city and compares them with those in the case cities. This chapter illustrates the urban design project in Tongzhou—the subcenter of Beijing, to verify the feasibility of the framework. The result shows that this framework can provide more reasonable and scientific reference for the urban design practice.

Keywords New data environment · Urban form · Case study · Expansion-oriented · Urban design

7.1 Introduction

In urban planning practices, there are two methods that support planning, decision-making, and project generation. First, in the field of quantitative urban studies, the planning and decision-making at various geographic scales are mainly supported by urban modeling, which can simulate economic, environmental, and social impacts on urban development. In particular, strategic scenario analysis for policies aimed at large geographic scales can help decision-makers anticipate the impacts of the proposed policy changes comprehensively and therefore mitigate the potential

Y. Long, E. Zhang, *Data Augmented Design*, Strategies for Sustainability,
https://doi.org/10.1007/978-3-030-49618-0_7

planning risks (Guay and Waaub 2019). For example, large-scale urban models, which are tools for quantitative analysis that aim to represent the systematic evolution at the urban and regional levels, can be used to simulate and analyze the change in land use, the interaction between transport and land use and that between the housing market and public services. This kind of modeling can support decision-makers in determining the future directions of planning areas (Long and Shen 2015). Second, in the specific planning and design projects, planners attempt to provide references for the regeneration of planning programs by studying cities that have good built environments; this method is called a case study. However, as one of the vital methods for planning projects, depending on the limited documents or subjective field research, case studies, which are mainly empirical perceptions and qualitative analyses, have not played an effective role in planning projects.

How can urban case studies be applied to the development of planning programs more effectively? In current urban planning studies, the features of the urban built environment have been described in the main bodies of the following papers. However, these researchers always mention the possibility of case studies but do not demonstrate the process of these case studies. For example, Yang et al. (2017) attempted to provide references for the construction of green spaces by comparing the multiple scales of green spaces among Beijing, London, New York, and Paris. Leng et al. (2016) attempted to provide planning advice for the construction of changing metropolitan areas by describing the spatial scale, functional organization, spatial structure, industrial layout, and transportation network in other countries' metropolitan areas. Chen et al. (2017) provided references for the construction of the central district by studying the mixed functional modes and the relationship among the urban factors of the bay area in Singapore. However, these studies only showed the possibility of case studies but did not demonstrate how to use the conclusions of case studies in planning and design projects.

Research advances in the field of quantitative urban built environment research have provided new possibilities for improving the method of case studies. In terms of the research methods, Ye and Zhuang (2017) reviewed how to analyze the urban built environment and factors related to spatial form using quantitative methods. In the analysis of the spatial form in a single city, the space syntax, spacematrix, and MXI (mixed-use index) are mainly used to quantitatively analyze the street networks, building types and intensity, and degree of mixed land use (Hillier and Hanson 1984; Hoek 2008; Berghauser et al. 2010; Ye and Zhuang 2017). Ewing and Cervero (2010) constructed a 5D model of the built environment, which included the density, diversity, design, accessibility, and distance to public facilities, so that the quality of the built environment could be analyzed quantitatively. Handy et al. (2002) improved this model by analyzing indicators including density and intensity, the degree of mixed land use, the connectivity, the scale, and the beauty of the street in both the community and the region. These methods and indicators can also be used in the analysis of urban built environments in case studies.

In the new data environment, the quantitative analysis mentioned above has advanced further. The related empirical studies include the use of OSM (OpenStreetMap) and POI (point-of-interest) data to identify the land use automatically (Liu and Long 2016) and using POI data and cellphone signals to construct indexes for quantitative street activity analysis (Shen and Li 2017). Street view images are used to evaluate changes in street quality and space (Tang and Long 2019). The advances of these methods provide multiple data sources and the possibility of analyzing urban built environments in case studies.

Long and Shen (2015) proposed DAD (Data Augmented Design) in 2015, which is a methodology for urban planning and design. Supported by new data and algorithms, DAD can help deepen the understanding of the multidimensional relationships between the built environment and behavior. Based on this methodology, they proposed the TSP (time-space-people) model, which was supported by the new data environment in large-scale urban design, and proposed the further assumption that using the TSP model to identify the good genes of different spatial forms and extract the spatial form modes to support design programs (Long and Shen 2016). This assumption provided the possibility of combing the quantitative urban built environment analysis with the development of the design program and has been applied in data-driven urban design efforts in historical districts, which have explored the application of the TSP model in redevelopment-oriented planning. Based on the TSP in the DAD framework, using the quantitative urban built environment analysis in a new data environment, this chapter constructs the research framework of a quantitative case study that is suitable for both redevelopment-oriented and expansion-oriented urban design and then applies this framework to large-scale urban design in the Tongzhou subcenter to verify the feasibility of this framework. Finally, this paper provides rational and scientific support for the generation of spatial forms in urban design projects by exploring quantitative case studies.

7.2 Research Framework

Ignoring the factors that will impact the formation of the urban built environment during the process of urban development, this study provides the assumption that the built environments of cities in case studies are those of cities after the complementation of the planning and design projects. Based on this assumption, the urban built environment in the case needs to be quantified first, which can better support the generation of the spatial form in planning and design projects. There are four steps in the framework. The first step is the analysis of the built environment of case cities and the extraction of the spatial indicators in every spatial category, such as the street network, the building density, and the land use mixture. The second step is to quantify these indicators and abstract them into the spatial form modes that are considered urban genes. These urban genes are classified when added into the "urban gene bank." In the third step, according to the situation of the city in the planning project, the study selects suitable urban genes in each urban gene bank, then combines them into the planning project and adjusts them flexibly according to the local conditions. Finally, after the design project, the study evaluates the indicators of the built environment in the planned city and compares them with those in the case cities (Fig. 7.1).

Specifically, in the quantification step for the built environments of the case cities, we first choose suitable cities to be analyzed as cases according to the type of

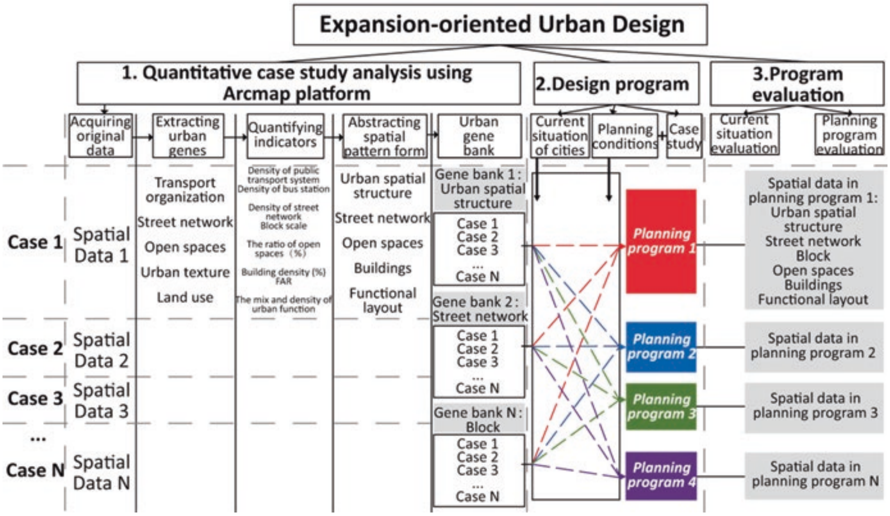

Fig. 7.1 Research framework

city in the planning project. For expansion-oriented planning projects, new towns, such as industrial new towns or residential new towns, that have developed to maturity should be chosen as cases. For the redevelopment-oriented planning projects, choosing corresponding areas, such as the CBD or historical district, as cases is appropriate. After the case cities were confirmed, we used ArcMap as the working tool and acquired the spatial data for the cases from open data platforms, including OpenStreetMap and social networks such as Weibo, Google, or Baidu maps, and then classified these data into four dimensions—the spatial form, building function, activity, and viability. In each dimension, we chose the corresponding indicators to analyze the above aspects. For example, for the dimension of spatial form, we choose street networks, open spaces, and urban textures. Then, we quantified these indicators by using various tools and methods. For example, we used building density and FAR to describe the urban texture. For cases in large-scale urban areas, indicators with different scales needed to be calculated separately. For example, the street networks in central cities and suburbs are organized differently and should be calculated separately so that the following analysis will be more accurate. Finally, as for the case studies in the expansion-oriented urban areas, indicators in the new towns and central cities need to be compared to verify the developmental stage of the new town so that those new towns that have not yet completed development can be excluded from the case. For the case study in redevelopment-oriented urban areas, the indicators from different historical periods need to be compared.

In the mode abstraction step, we first abstracted the indicators that had been quantified into the spatial form mode. In this mode, the different values of building density and block FAR (floor area ratio) composited different form modes. This mode comprises the "urban genes" of the city, which can reflect the relationship between the data and the urban spatial form. Second, we added the "urban genes" into the "urban gene bank" to construct the categories of the "urban gene bank," including the urban structure, street network, open space, building organization, and land use. Supported by the open data, the urban spatial modes in a large number of cities could be abstracted so that the "urban gene bank" can be improved continually as more urban genes are added. Through these steps, the "urban gene bank" of the cities in the case could be built.

For the design program, according to the current situation of cities and planning strategies, we chose the urban genes in each "urban gene bank" to put into the city design and conducted some simulations. In this way, several design schemes can be presented to reduce uncertainty in urban development. After the design program was completed, the indicators of cities in the cases could be compared with those of the designed cities both in the current situation and in the planning program.

In this framework, the analysis was not limited to complicated calculations with ArcMap as the working tool and the acquisition of data from an open data platform. Moreover, the urban genes of each city can be used in many design programs so that the efficiency of planning practices can be improved.

7.3 The Application of Quantitative Case Study Framework in an Urban Design Project

Other than for nuances such as choosing and classifying indicators, this framework was applicable to planning and design projects both in redevelopment-oriented and expansion-oriented urban design. This research used the Tongzhou subcenter as the study area for empirical research to verify the feasibility of this framework for urban design projects in expansion-oriented urban designs. This project mainly focused on the quantitative case study of urban spatial form generation.

7.3.1 Design Site

Located in the eastern Beijing metropolitan area and 23 km away from the center of Beijing, the total area of the Tongzhou subcenter is 155 km^2. The current population in the city is approximately 800,000 and that in the planned area is predicted to reach 1.5 million. It is expected to take on part of the capital function and serve as a new integrated city to relieve the population pressure in Beijing (Fig. 7.2).

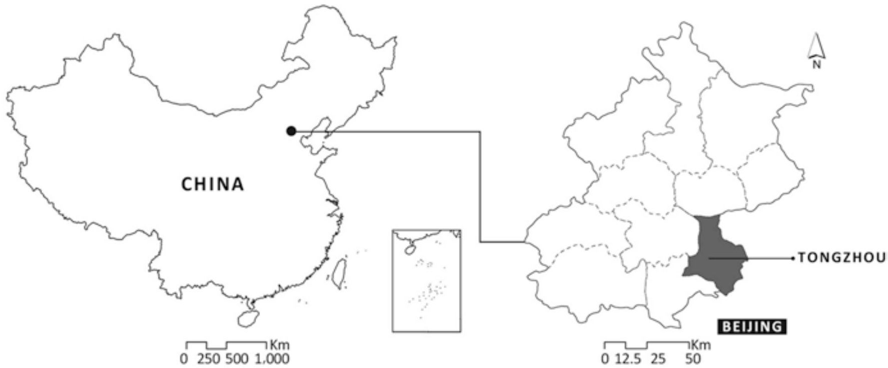

Fig. 7.2 The location of the design site

7.3.2 The Selection of Cities for the Case Studies

As the subcenter of Beijing in the future, Tongzhou is more unique than other new cities. In this context, new towns in metropolitan areas in developed countries can be good cases to provide references for the urban design of Tongzhou. According to the size of Tongzhou, the distance from Beijing, and the urban design goals, which include the public transport planning and urban functions of Tongzhou, as well as the accessibility of the data in OpenStreetMap and satellite images, this research chose three new towns that have developed to maturity and are similar to the Tongzhou subcenter (Fig. 7.3). They are Yokohama, which is around Tokyo; Almere, which is around Amsterdam; and Marne-la-Vallée, which is around Paris. Yokohama, which is the largest new town in the Tokyo metropolitan area and is located 30 km away from Tokyo, represents cities that have developed around an area with a high density of rail transit stations with. It was redeveloped in the 1950s and has an area of 232 km^2; the population in 2010 was 3.69 million. Almere and Marne-la-Vallée represent new towns in Europe. Almere, which is located in the Amsterdam metropolitan area 20 km away from Amsterdam, was developed in the 1970s, and has an area of 131 km^2; the population in 2011 was 190,000. Marne-la-Vallée, which was located north of the Paris metropolitan area 10 km away from Paris, was developed in 1969. Its area is 152 km^2, and the population in 1999 was 240,000. There are evident differences between these three new towns. The mode of urban expansion in Yokohama is TOD, in Almere is a strong single center, and in Marne-la-Vallée is a strip shape. The aim of choosing the cities with different development modes of urban spaces was to extract urban genes from different urban spatial forms and determine which one was most suitable as the case for the urban design of Tongzhou.

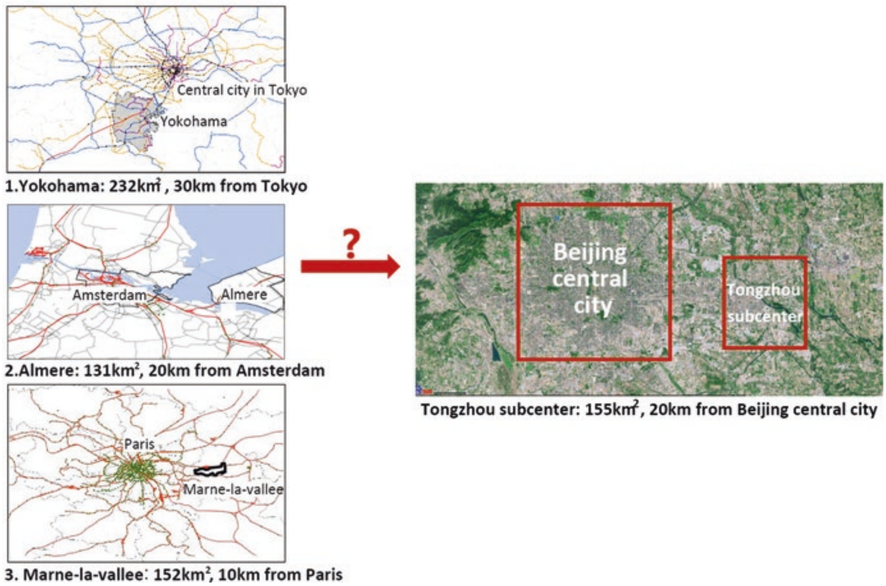

Fig. 7.3 The locations of the three new towns and their nearby central cities

7.3.3 The Analysis of the Three New Towns as Cases

Collecting Data and Qualifying Indicators

As one of the most successful websites that provides geographic information, OpenStreetMap provides a large amount of data, including urban networks, blocks, and buildings (Haklay and Weber 2008). The quality and completeness of the data for European cities and famous cities have achieved the accuracy of topographic maps (Haklay 2010; Girres and Touya 2010). Therefore, our studies were mainly based on these data. First, we collected spatial data for the new towns and their central cities from OpenStreetMap and built five categories of indicators, which included street networks, transport systems, open spaces, building textures, and urban functions according to the urban spatial form and function. Then, we quantified the indicators at the analysis unit of the land parcel. Specifically, we used the road density (km/km^2) and the public transport station density (number/km^2) to quantify the transport system and the street network density (km/km^2) and used the size of the block (hm^2/block) to quantify the street network. We also used the ratio of open space (%) to quantify the open spaces, use building density (%; floor space/block area), FAR (building area/block area) to quantify the building texture, and used the urban function mix ($\text{mix} = -\sum n_i = 1(p_i * \ln p_i)$ where n represents n categories and p_i represents the POIs in ith category/the POIs in all land parcels) and urban function density (number/km^2) to quantify the urban functions. Finally, we calculated the indicators in the land parcels and compared them with those in the central

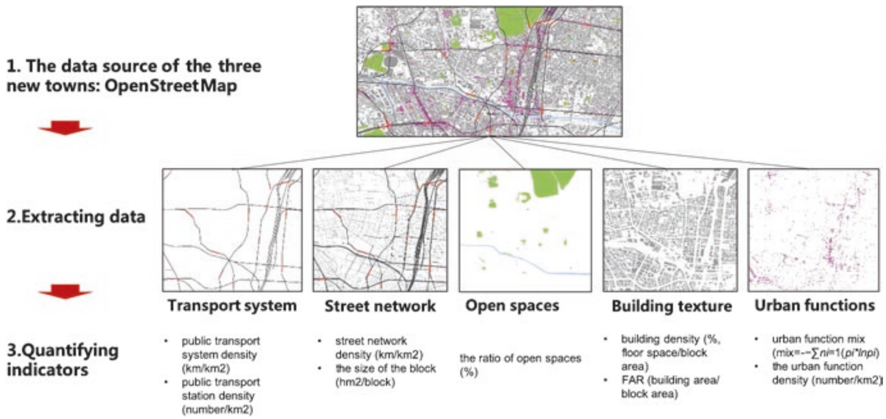

Fig. 7.4 The process of analysis of the new towns

cities so that the development stage of each new town could be understood (Fig. 7.4). The result showed that the three new towns had not only formed urban functions and population agglomerations but had also formed complete street networks and buildings, which implied that these three new towns had developed to maturity and could be studied as cases.

The Results of the Quantified Indicators

The results of quantified indicators of the three new towns showed that compared with the other two new towns, Yokohama was developed with high density. Specifically, the building density in both the new and old centers of Yokohama used higher than that in the other urban areas. The building density in the whole city was much higher than that in the other two new towns. In addition, in Yokohama, the public transport system density, the public transport station density, and the street network density were higher, and the sizes of the blocks were smaller. This was related to the long history of urban development, population density, and land use policies in Japan. Almere and Marne-la-Vallée had the same the building density, which was approximately 20% lower than that in Yokohama (50–60%). A lower building density means a higher ratio of open space. The average street network was approximately 20 km/km^2, and the size of the blocks was approximately 4–5 hm^2. In terms of the urban function density, in Yokohama, it was much higher in the old center and around the railway stations than in the other urban areas, but it showed lower values in both new European towns (Table 7.1). The urban function density further demonstrated that the urban functions in Yokohama were distributed around the railway stations, and in the other two new towns, the urban functions just agglomerated in the city center (Fig. 7.5 and Table 7.1).

Table 7.1 Quantifying indicators of spatial data in the three new towns

		Railway system density (km/km^2)				Urban function density (number/km^2)
Name	Area/indicators	Railway station density (number/km^2)	Street network density (km/km^2)	Ratio of open spaces (%)	Building density (%)	Urban function mix
Yokohama	Whole city	1.19/0.2	20.7/1.68	6	32.10	10.2/0.54
	New center	0.89/0.4	22.8/2.16	3.90	60	13.3/0.61
	Old center	1.14/0.8	24.2/1.55	0.30	57.80	25.4/0.52
	Around station (500 m)	–	30.4/1.86	8	48.90	23.2
	Around station (800 m)	–	23.8/1.64	7	47.6	17.4
Almere	Whole city	0.14/0.05	20.7/4.0	57	21.80	8.4/0.21
Marne-la-Vallée	Whole city	0.41/0.07	17.2/5.25	36.50	20	6.2/0.34

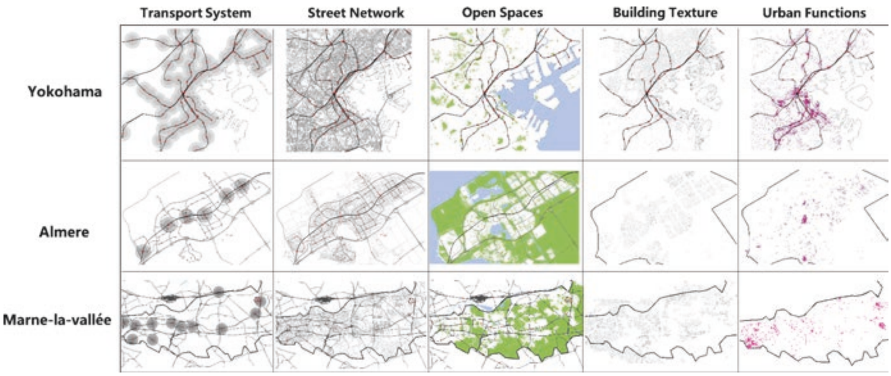

Fig. 7.5 Visualization of the spatial data in the three new towns

Building the "Urban Gene Bank" of the Three New Towns

We built the "urban gene bank" by abstracting the urban spatial form modes based on the quantification of the indicators. For Yokohama, through the analysis above, the urban spatial form modes of the whole city could be generalized as "being developed around the dual center and railway stations." The urban spatial form modes around the city center and the railway stations were different according to the different values of indicators in these two areas. For the two new towns in Europe, the urban spatial form modes of the whole city could be generalized as "being developed in several clusters," and the clusters were connected by the railway and separated by green spaces. The size of each cluster was 400–500 hm^2. The urban

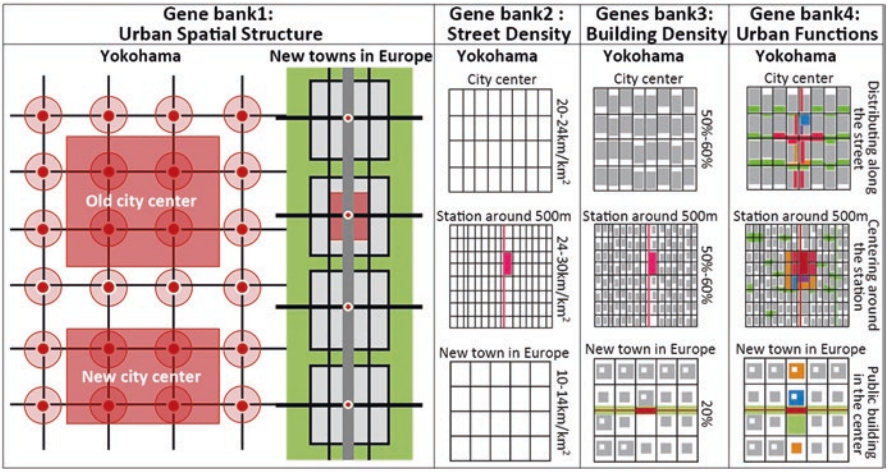

Fig. 7.6 "Urban gene banks" of the three new towns

spatial form modes in each cluster could be generalized as having a single center and low street network density and building density.

According to the analysis above, this research constructed the genes related to the urban spatial structure and urban spatial form at different scales by abstracting the values of the street density, building density, and urban function layout and finally built the "urban gene bank" of the three new towns (Fig. 7.6).

7.3.4 *The Generation of Urban Design Programs for the Tongzhou Subcenter Based on the Case Studies*

After the case studies, we choose some suitable urban genes from the "urban gene bank" to support the generation of an urban design program for the Tongzhou subcenter by calculating the development intensity of the new town according to the master plan. The results showed that the railway system density (1.03 km/km^2) and the railway station density in the master plan were similar to those in Yokohama. Therefore, during the generation of the urban spatial form around the railway stations in the city center, the program uses the urban genes in the city center of Yokohama for reference, in which the average street network density around the railway station is 24–30 km/km^2. In addition, this study chose clusters as the unit of urban development so that phasing development would be achieved through mixed use and urban sprawl would be prevented by the presence of open spaces between each cluster. In addition, it was not applicable to develop the whole city with high intensity based on the assumption that the development density in the urban design programs could accommodate the planned population. Therefore, this study used the urban genes of Almere and Marne-la-Vallée, in which the clusters were sepa-

Fig. 7.7 Urban spatial form around the railway stations and in clusters

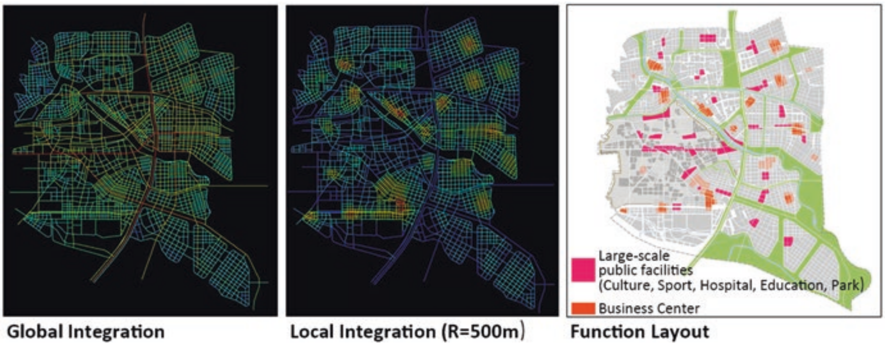

Fig. 7.8 Urban function layout based on the space syntax

rated by large-scale open spaces, for reference. The size of each cluster was 400–500 hm^2, and the average designed street density was 20 km/km^2, which was the average street density of these two new towns. In this way, the urban spatial form, which was organized by clusters and railway stations, was generated (Fig. 7.7).

In terms of the urban function distribution, according to the results from space syntax, large-scale public facilities should be planned in areas with high general integration, and pedestrian-oriented facilities should be planned in areas with high partial integration. The result showed that the high general integration was along the arterial roads where the large-scale public facilities would be planned, while the high partial integration was around the railway stations where the business and office buildings would be planned (Fig. 7.8).

Finally, we evaluated the indicators both in the current situation and the planned program in Tongzhou and compared the result with those in the three new towns. We found that, compared with the new towns in the case cities, the street network density, building density, and urban function density of the current situation in Tongzhou were lower, and the block size was larger. As a result, we adjusted and improved the street network density, building density, block size, and public services facilities so that they have a good urban spatial form and could allow various activities in the future.

7.4 Conclusion and Discussion

Supported by the new data environment, the quantitative methods for the built environment research in DAD can be involved in quantitative case studies, which is suitable for redevelopment-oriented and expansion-oriented urban designs, especially for the latter. This chapter proposed a detailed framework for rational and scientific case studies. In total, there were four main steps in the framework.

First, suitable cases should be selected according to the characteristics of the design site. Then, the indicators, including various form of elements, are extracted and quantified. These quantified elements, which are regarded as urban genes, are be added into the "urban gene bank." Next, in the specific urban design process, some urban genes are chosen to support the design generation according to the current situation and planning strategies. Finally, when the designs are completed, indicators in the planning program are measured and compared with those in the current situation and case cities.

To better elaborate the framework, we used the Tongzhou subcenter as the study area for empirical research, which is a typical expansion-oriented urban design. First, we collected the data of the case cities from the open data platforms and classified these data according to their spatial dimensions. Second, we built an "urban gene bank" for the case cities based on quantified spatial elements. Third, we applied some urban genes in the bank for the urban design project to support the design generation. Finally, we evaluated the indicators in the design and compared the results with case cities and the situation of the design site without a design. The research showed that the results of the quantitative built environment analysis can be used in the regeneration of expansion-oriented urban design. The quantitative case study does not simply simulate the spatial form of the case cities; instead, it emphasizes the references of the urban spatial models based on the quantification and abstraction of the indicators. In other words, quantitative case sstudies can support urban planning in a rational and scientific way and help generate the urban spatial form in expansion-oriented areas.

However, there are still some problems that need to be explored further. First, the framework in this research mainly focused on the urban spatial form and did not consider the institution factor in the planning system, which would impact the implementation of the planned project. Second, in empirical research, we only focused on quantitative case studies that involve spatial forms and functions such as street networks, blocks, building textures, and urban function layouts in expansion-oriented urban areas, and we selected only three cities for case studies. More indicators and case cities should be considered in future studies. To remedy these limitations, there are four steps we will take in the future. First, a quantitative case study towards multiple dimensions, such as urban vitality and people's activities, will be involved. Second, the urban gene bank will be improved based on the urban genes from more cities so that the errors resulting from the case deficiencies would be decreased. Third, the technology of automatic identification and urban gene extraction will also be studied to improve the efficiency of case studies. Finally, specific quantitative case studies in redevelopment-oriented urban design should be explored.

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Chapter 8
Defining the Density of the Xiong'an New Area Based on Global Experience

Abstract The framework described in Chap. 7 is also applied in the official planning workshop of Xiong'an New Area. As the establishment of the Xiong'an New Area is a major historic and strategic choice for China, its spatial planning is the fundamental guideline for its development. This chapter introduces the work we have done in this workshop, which aims to provide a quantitative case study of urban density for the development of urban design standards for Xiong'an New Area. This chapter emphasizes on various densities of different urban functions, in which 30 cases with four urban functions are selected and spatial indicators including the road density, average block scale, building density, FAR (floor area ratio), and average number of floors are calculated. These characteristics are abstracted as spatial form modes in an urban "gene bank." The result in this research provides a rational and scientific support for the generation of urban form in Xiong'an New Area urban design project.

Keywords New data environment · Urban density · Case study · Urban design · Xiong'an New Area

8.1 Introduction

8.1.1 The Construction of the Xiong'an New Area

In 2019, the population of Beijing reached more than 21 million, and it is predicted to reach 26.5 million in 2020 (Ding et al. 2018). The excessive population has brought a series of problems to the city such as traffic congestion, high housing prices, and resource overload. The deeper reason for these urban problems is the large number of noncapital functions that Beijing carries. To solve these problems, it is necessary to disperse Beijing's noncapital functions to other places for special functions. After repeated comparisons, scientific research, and the rigorous

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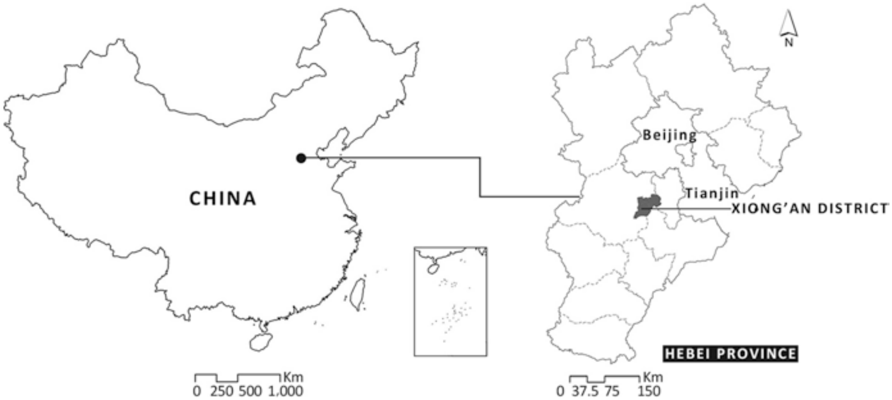


Fig. 8.1 The location of the design site—the Xiong'an area

debate among experts, the construction of the Xiong'an New Area was finally determined.

The planning area of the Xiong'an New Area involves three counties, Xiongxian, Rongcheng, and Anxin, in Hebei Province and their surrounding areas, which are located in the hinterland of Beijing and Tianjin (Fig. 8.1). It is starting with an area of approximately 100 km^2 and will reach approximately 200 km^2 in the medium term, and its long-term area will cover approximately 2000 km^2. On the whole, this region has incomparable geographical advantages and convenient traffic. There are many highways and railways in this region, which can form a basic half-hour commuter circle with Beijing, Tianjin, and Shijiazhuang. The ecological environment of the Xiong'an New Area is also excellent, with rich resources and a good ecological carrying capacity. In addition, there is little existing development, meaning that there is great potential for high-quality development and construction (Xinhua 2017).

8.1.2 Introduction to the Workshop

The Xiong'an New Area is China's millennium plan, and its planning standard is very important. It is necessary for us to look back at history, expand the vision to the global level, and fully learn from international experiences to make Xiong'an a world-class city. To implement the planning work of Xiong'an with a high standard and high quality, the China Academy of Urban Planning and Design took the lead in organizing the planning workshop for the Xiong'an New Area. This workshop was held from April 25th to May 10th, 2017, emphasizing the optimization and improvement of the overall layout plan of the Xiong'an New Area Master Planning and the Start Area Regulatory Planning. Urban spatial form is a very important component of urban master planning and urban regulatory planning, which are the basis for a city's political, economic, social, and cultural activities. This research is based on the workshop, allowing us to provide a case study of urban spatial form for the setting of urban design standards for the Xiong'an New Area.

8.1.3 Research Objectives and Main Contents

The purpose of this workshop was to help the Xiong'an area developing various standards for planning. Generally, scholars and planners use the secondary literature, existing planning designs or foreign indicator systems as references and use current photos, traditional data, and new data for qualitative and quantitative analysis and experience summarization. To that end, cities that have good built environments can also serve as cases for us to obtain potential planning and design standards. The new data environment provides good opportunities to help analyze excellent case cities and calculate relevant indicators, helping us summarize the universal merits and supporting the design process.

The planning and construction of Xiong'an need to highlight the ecological civilization and social innovation. Innovation should be the fundamental driving force for the development of a district, allowing it to then attract high-tech innovative talent and teams and to finally strive to create an innovative highland and a new technology city. The goal of the planning of its spatial form is to achieve a compact and mixed urban spatial layout, including the creation of rich hybrid unit development and appropriate building density control. Therefore, the research objective of this project is to use the quantitative case study method (see the previous chapter for details) to learn from the density of the most advanced development zones and to provide empirical support for the construction of Xiong'an.

This chapter first introduces the overall research framework of this project, which includes case selection, data collection, data analysis, and a summary of urban spatial forms. Subsequently, the research results of the project are elaborated based on different functional areas. Finally, a review of the method and main conclusions is carried out, and the potential application of the research method in the future is also discussed.

8.2 Research Framework

8.2.1 Research Design

Based on the DAD (Data Augmented Design) framework proposed by Long and Shen (2015), this research applies a quantitative case study to help in the design and construction of Xiong'an. This project uses the street block as a basic analysis unit for the case study. Blocks play the role of a basic spatial organizational unit in traditional Western cities. They are the main research object of urban morphology and architectural typology, and they are also the medium to help us understand the architectural form and the overall spatial form of the city. The whole framework of this project includes four steps (Fig. 8.2). The first step is choosing some developed zones and new towns that are comparable with Xiong'an as cases and determining the data collection area of these case cities. The second step is downloading relevant

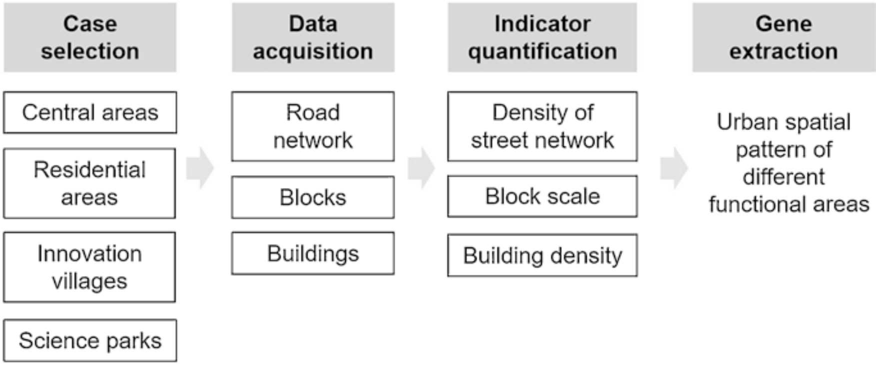


Fig. 8.2 The research framework

data from OSM (OpenStreetMap), including the road network, blocks, and buildings with footprints. Then, following Ye et al. (2018), we extract spatial indicators to reveal their construction density in every spatial category, such as the average block scale, road density, and building density. Finally, we quantify these indicators and abstract them into different modes of spatial form, which are considered urban genes for the design process.

8.2.2 The Selection of Case Areas

At the beginning of this project, we first selected suitable cases and research areas based on the situation of Xiong'an. At present, China is creating a new era of the ecological civilization, which will also be reflected in Xiong'an. This means no high-level buildings, ecological friendliness, and vibrant urban public space. In this context, we believe that the reference cases of Xiong'an can mainly consist of some new cities and districts in Europe, where the cities are not very large and have only a few high buildings but the scenery is beautiful, especially because many streets are very human friendly and vibrant. According to the development goal of Xiong'an, this research chooses several cases of different types, including urban central areas, residential areas, innovative villages, and science parks. Then, we define the research area of each case based on the accessibility of relevant data.

Central Areas

A central area is mainly the old city of some major cities in China and foreign countries. These old cities are full of history and vitality, and their development density is relatively low, which is consistent with the development orientation of the Xiong'an New Area. These old cities include the French Concession in Shanghai, China, and the old cities in Beijing, Hangzhou, and Chengdu in China and Paris and

Berlin. In addition, we choose the Futian CBD in Shenzhen, the Bund in Shanghai, Singapore's Marina Bay, the Hamburg New Town, and the downtown areas of Atlanta and St. Louis to represent central areas of modern international cities that combine different functions, including offices, culture, leisure, and business travel. These areas can provide a reference for Xiong'an to help create a diverse and functional mixed urban center (Table 8.1).

Residential Areas

Residential areas are chosen from low-rise historical settlements developed in the old city, such as the Jing'an Villa District and Zhangjia Garden in Shanghai. The Jing'an Villa District and Zhangjia Garden are microcosms of traditional residential areas in Shanghai. In addition, we choose the OCT in Shenzhen as the representative of high-quality residential areas in modern Chinese cities. In view of the development orientation of the establishment of a green, ecological, and livable new urban area in Xiong'an, we select some new eco-friendly communities in Europe as cases, including Hammarby in Sweden and the City of Tomorrow in Malmö, Lisfield (Rieselfeld) in Germany, Vauban and Tübingen-Südstadt, and the Borneo-Sporenburg settlement in the Netherlands. These settlements are examples of sustainable urban development (Table 8.2). The interiors of the settlements are mostly low-rise and multi-story buildings developed with high density, where street shops and office spaces enhance the mix and vitality of the functions in these streets.

Innovation Villages

The Xiong'an New Area undertakes the task of dispersing Beijing's noncapital functions, and it will contain several famous universities, national research institutes, and innovation platforms. Therefore, the development of high-end and high-tech industries based on science and education institutions has become an important goal of the planning and construction of Xiong'an. We choose South Lake Union in Seattle, San Francisco's Mission Bay, and Heidelberg University City as cases (Table 8.3). South Lake Union features e-commerce and life sciences and many well-known companies and institutions, such as Amazon and the Gates Foundation.[1] San Francisco's Mission Bay is developed under the auspices of the University of California, San Francisco, and Mission Bay campus, attracting research institutions and companies in the biosciences.[2] Patrick Henry Village in Heidelberg is defined as the knowledge city of tomorrow, where there are mixed functions including residence, work, and production.[3]

[1] https://www.discoverslu.com/about/#slu-history.

[2] https://www.ucsf.edu/about/locations/mission-bay.

[3] https://www.e-architect.co.uk/germany/patrick-henry-village-in-heidelberg-phv.

Table 8.1 Research area and urban texture of central areas for case study

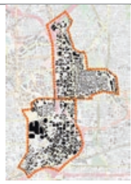
			
The Bund in Shanghai, China	Old French Concession in Shanghai, China	Futian CBD in Shenzhen, China	Old City in Beijing, China
			
Old City in Chengdu, China	Old City in Hangzhou, China	Marina Bay in Singapore	Soho District in London, UK
			
Knightsbridge and Belgravia in London, UK	Covent Garden in London, UK	St. James in London, UK	Milbank in London, UK
			
Friedrichstraße in Berlin, Germany	Potsdamer Platz in Berlin, Germany	HafenCity in Hamburg, Germany	Downtown Atlanta, US
			
Downtown St. Louis, US			

Table 8.2 Research area and urban texture of residential areas for case study

			
Jing'an Villa District and Zhangjia Garden in Shanghai, China	OCT (part 1) in Shenzhen, China	OCT (part 2) in Shenzhen, China	Hammarby Sjöstad in Stockholm, Sweden
			
Sweden-Malmo Western Harbor in Scania, Sweden	Rieselfeld in Freiburg im Breisgau, Germany	Vauban in Freiburg, Germany	Südstadt in Tübingen, Germany
			
Borneo Sporenburg in Amsterdam, Netherlands			

Table 8.3 Research area and urban texture of innovation villages for case study

			
South Lake Union in Washington, US	Mission Bay in San Francisco, US	University Research Park (University of Wisconsin) in Madison, US	Patrick Henry Village in Heidelberg, Germany

Table 8.4 Research area and urban texture of science parks for case study

			
Cao Hejing Hi-Tech Park in Shanghai, China	Silicon Roundabout in London, UK	Messestadt Riem in Munich, Germany	One North in Singapore

Science Parks

The "Hebei Xiong'an District Planning Outline" report proposes that the Xiong'an New Area will focus on the development of next-generation communication networks, the Internet of Things, big data, cloud computing, artificial intelligence, the industrial Internet, network security, and other information technology industries and adhere to the integration of production and employment, as well as a balanced industrial spatial layout. Therefore, we choose the Cao Hejing Hi-Tech Park in Shanghai, Silicon Roundabout in London, Messestadt Riem in Germany, and One North in Singapore as cases, which all effectively blend living and working places and create high-quality and high-energy technology parks (Table 8.4).

8.2.3 *Data Sources*

The new data environment provides a new lens for studying the patterns of urban form. After the selection of study cases, we use ArcMap as the basic working platform and collect the spatial data of the cases from an open data platform (OSM, OpenStreetMap), including the road network, blocks, and buildings. In addition, for the cases in China, we acquire building data from a Chinese Internet map platform, which contains the distribution and floor numbers of each building. We vectorized the building base in ArcGIS and registered the coordinates of the building data.

8.3 Quantitative Construction Density Analysis for Typical Urban Areas

We identify some indicators that need to be measured in terms of urban spatial form (Table 8.5), including the average block scale, the floor area ratio (FAR), building density, the average number of floors, and road network density. The floor

Table 8.5 Indicators and data sources

Indicator	Description	Data	Data Source	Analysis method
Road density	Street network density	Road network	OpenStreetMap	Total street length/land area
Average block scale	Average block area	Blocks	OpenStreetMap	Total block area/block count
Building density	Building density	Buildings	OpenStreetMap	Total building floor area/land area
Floor area ratio (FAR)	Average floor area ratio	Buildings	Gaode map	Total building area/land area
Average number of floors	Average floor numbers	Buildings	Gaode map	Total floor numbers/building count

area ratio and average number of floors are estimated only for the Chinese cases. Then, we quantify the indicators, with the land parcel as the unit. Specifically, we select the block scale (hm^2) and road network density (km/km^2) to quantify the road network characteristics, use building density (%, building floor area/land area), and the floor area ratio ((total building) area/plot area) to quantify the texture of the building, and select the average number of buildings to quantify the three-dimensional form of the city. Finally, we abstract the modes of spatial form for different functional areas.

8.3.1 Central Areas

Among the central areas, the old city in Chengdu has the largest block scale (4.90 ha), followed by the French Concession in Shanghai (4.56 ha) and the old city in Beijing (4.00 ha). Covent Garden in London has the smallest average block scale (0.73 ha), followed by Soho in London (0.91 ha). The block scale of the old cities in China is significantly higher than that of those in other countries, except for Hamburg New Town's block scale (4.00 ha). The road network with the highest density is the downtown area of St. Louis (6.22 km/km^2), followed by Soho (5.98 km/km^2) in London and Haven City in Germany (5.34 km/km^2), while the network density with the lowest density is in the old city in Beijing (1.35 km/km^2) and Chengdu (1.49 km/km^2). The highest density of buildings is in Covent Garden (79%) in London, followed by St. James (67%) in London and Friedrichstraße (66%) in Germany. The lowest building density is in the central area of Atlanta (36%) and the Futian CBD in Shenzhen (Table 8.6).

We analyze the country-by-country statistics for each indicator based on the geographic location of each case (Fig. 8.3). The old cities in Beijing, Hangzhou, and Chengdu, and the French Concession in Shanghai are recognized as China's old cities. The Futian CBD in Shenzhen and the Bund in Shanghai are regarded as the modern centers of China. Friedrichstraße and Potsdamer Platz are categorized as old towns, and Haven City in Berlin is classified as a new town of Germany. The

Table 8.6 Quantified indicators of the spatial data of central areas

Cases	Average block scale (ha)	Road density (km/km^2)	Building density (%)	FAR	Average number of floors
The Bund in Shanghai	1.91	4.26	66	4.8	7.4
Shanghai Old French Concession	4.56	1.91	39	1.6	4.2
Shenzhen Futian CBD	2.66	4.49	42	5.8	13.5
Beijing Old City	4.00	1.77	41	1.9	2.4
Chengdu Old City	4.90	1.49	36	1.8	6.0
Hangzhou Old City	3.52	2.04	40	1.9	6.2
Singapore-Marina Bay	1.80	5.04	43	–	–
London- Soho District	0.91	4.12	79	–	–
London-Knightsbridge and Belgravia	2.45	3.13	38	–	–
London-Covent Garden	0.73	4.78	79	–	–
London-St. James	1.04	4.26	67	–	–
London-Milbank	1.62			–	–
Berlin-Friedrichstraße	2.45			–	–
Berlin-Haven City	4.00			–	–
Berlin-Potsdamer Platz	1.27				
US.-Downtown Atlanta	2.16			–	–
US.-Downtown St. Louis	1.35			–	–

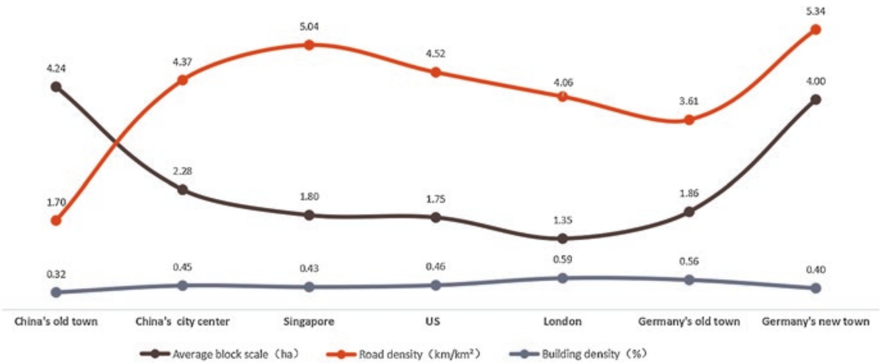


Fig. 8.3 The comparison of the urban spatial forms between different central areas

remaining areas are classified directly according to the country in which they are located. The results show that the urban spatial forms of China's old cities are mostly large scale with a thin road network, and high building density. The development mode of the old city centers in Europe is mainly a small block scale, dense road network, and high building density. The development mode of the districts in Germany tends to consist of a dense network and large block scale. China's

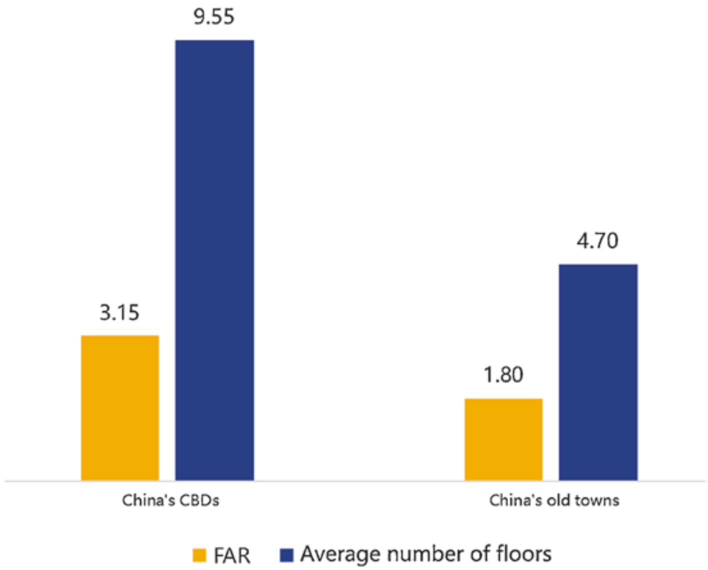


Fig. 8.4 The comparison of the urban spatial forms between Chinese central areas

modern urban centers, Singapore, and the US urban centers have smaller-scale blocks, dense road networks, and higher building densities.

From the perspective of the three-dimensional form of the city, the average FAR of Chinese CBDs (the Bund in Shanghai and Futian CBD) is 3.15, and the average number of floors of buildings is 9.55, with enclosed high-rise buildings dominating. The Chinese old cities have an average FAR of 1.80 and an average number of floors of 4.70 (Fig. 8.4).

8.3.2 Residential Areas

Among the residential areas, Shanghai's Zhangyuan has the largest block scale (10.37 ha), followed by Shenzhen's OCT (7.50 ha) and Sweden's Malmö (6.27 ha), while Vauban has the smallest block scale (0.91 ha). Zhangyuan has the road network with the highest density (7.10 km/km^2), followed by Vauban (4.17 km/km^2) and Rieselfeld in Freiburg, Germany (3.16 km/km^2). The road network with the lowest density is in the Shenzhen Overseas Chinese Town (1.35 km/km^2 and 1.69 km/km^2) and Jing'an Villa District in Shanghai's old city (2.15 km/km^2). The highest building density is in Jing'an Villa District (76%) in Shanghai's old city, followed by Borneo-Sporenburg in the Netherlands (52%) and Zhangyuan in Shanghai's old city (43%). The lowest building density is in the OCT in Shenzhen (15%) and Hammarby Sjöstad in Sweden (25%) (Table 8.7).

Table 8.7 Quantified indicators of the spatial data of residential areas

Cases	Average block scale (ha)	Road density (km/km^2)	Building density (%)	FAR	Average number of floors
Shanghai Jing'an Villa District	4.65	2.15	76	1.1	3.9
Zhangjia Garden	10.37	7.10	43	1.1	3.6
Shenzhen OCT-part 1	1.87	1.69	27	2.5	9.0
Shenzhen OCT-part 2	7.50	1.35	15	1.4	7.5
Sweden-Hammarby Sjöstad	2.66	2.97	25	–	–
Sweden-Malmo Western Harbor	6.27	2.31	29	–	–
Germany-Rieselfeld	1.04	3.16	32	–	–
Germany-Vauban	0.91	4.17	30	–	–
Germany-Tübingen Südstadt	1.61	2.50	26	–	–
Netherlands- Borneo-Sporenburg	1.53	2.71	52	–	–

The indicators, including the residential area, road network density, and building density of the residential area, are higher in Shanghai's old city than in the other cases. The new towns in Germany are mostly located in plains, and their development modes mostly involve a small block scale, dense road network, and high building density. The OCT in Shenzhen, Hammarby Sjöstad, and the Malmo Western Harbor in Sweden contain a certain area of natural open space, such as mountains and lakes in the residential area, and their block scales are larger and building density is lower compared with the other cases (Fig. 8.5).

From the perspective of the three-dimensional form of the city, the average FAR of the high-quality residential areas in Shenzhen is 1.95, and the average number of floors is 8.25, with high-rise buildings dominating. The average FAR of the residential area in Shanghai's Old Town Historic District is 1.1, and the average number of floors is 3.75, with multi-story buildings dominating (Fig. 8.6).

8.3.3 Innovation Villages

Regarding innovation villages, both University Research Park (University of Wisconsin) in the USA and Patrick Henry Village in Germany are university towns located on the outskirts of the city. They both have a low building density and a large block scale. There are more road networks inside University Research Park, realizing convenient transportation links inside the park. Patrick Henry Village in Germany has a huge block scale, the road network density is extremely low, and the

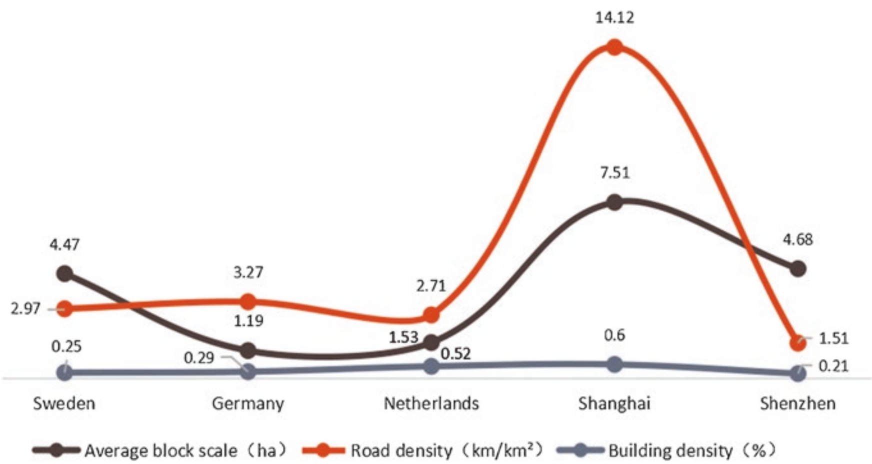


Fig. 8.5 The comparison of the urban spatial forms of different residential areas

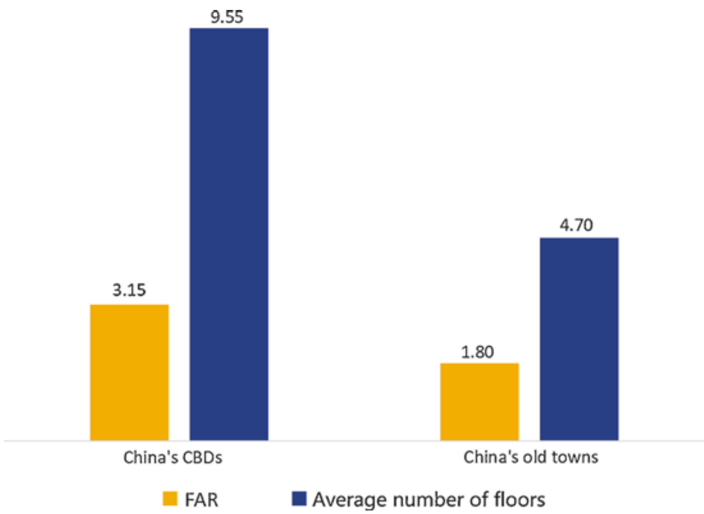


Fig. 8.6 The comparison of urban spatial forms of Chinese residential areas

space inside the park is totally open. Both South Lake Union and Mission Bay in the USA are located in the inner cities of the USA and are spatially shaped by small-scale neighborhoods, high-density road networks, and high-density buildings (Table 8.8 and Fig. 8.7).

Table 8.8 Quantified indicators of the spatial data of innovation villages

Cases	Average block scale (ha)	Road density (km/km^2)	Building density (%)
US.-South Lake Union	0.90	5.98	65
US.-Mission Bay	2.00	4.26	51
US.-University Research Park (University of Wisconsin)	5.95	7.63	22
Germany-Patrick Henry Village	13.89	1.65	15

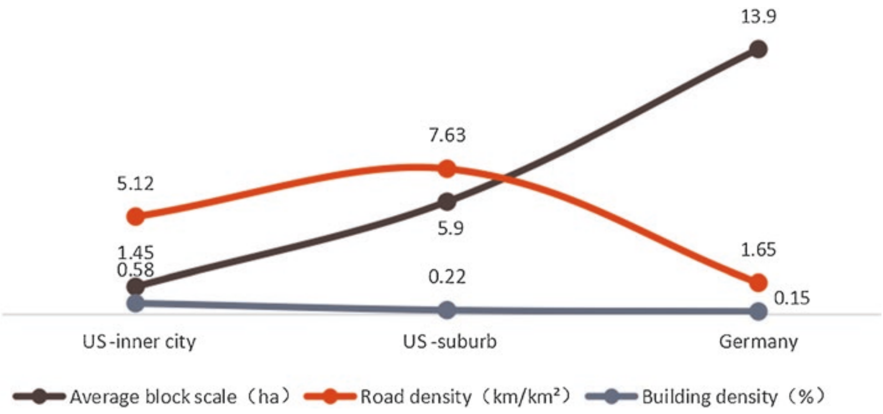


Fig. 8.7 The comparison of the urban spatial forms of different innovation villages

8.3.4 Science Parks

Regarding science parks, the Cao Hejing Hi-Tech Park in Shanghai has a large block size and low building density. The park implements a 40% greening rate and appropriately increases the FAR, making the environment in the park more pleasant. The other three science parks have small block scales and dense road networks. Among them, Silicon Roundabout in London and Messestadt Riem in Germany have higher building densities (Table 8.9 and Fig. 8.8).

8.4 The Construction of the Urban Gene Bank

By quantifying and summarizing various indicators of different types of areas, it is possible to abstract the development genes of different types of areas and to apply them for reference in the Xiong'an urban design project. We calculate the

Table 8.9 Quantified indicators of the spatial data of science parks

Cases	Average block scale (ha)	Road density (km/km²)	Building density (%)
London-Silicon Roundabout	1.2	3.20	46
Germany-Messestadt Riem	1.1	9.89	44
Singapore-One North	2.0	4.18	29
Shanghai-Cao Hejing Hi-Tech Park	12.7	0.81	24

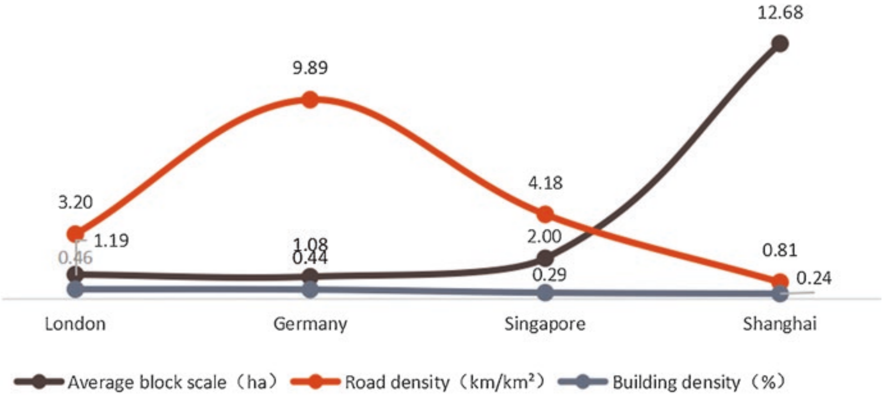


Fig. 8.8 The comparison of the urban spatial forms of different science parks

block scale, road network density, and building density for each case category. Considering the impact of results with extreme values, when estimating statistics, we remove the values at the top and bottom 10%, and the final results are shown in Table 8.9.

The results illustrate that the block scale of the central areas and science parks is relatively small, mostly ranging from 1.19 ha to 3.52 ha. In addition, these two types of areas have similar average road network densities of approximately 3.6 km/km². Moreover, they are shown in compact form, in which the building density of the central area is the highest among these functional areas, reaching 46%. The building densities of the other three types of functional areas are similar, ranging from 34% to 37%, which means that more open space and public space are available in these areas, thus improving the overall quality of space. The block scale of the residential areas is relatively large, and the average block scale is 3.18 ha. The road network density and building density of the residential areas are the lowest among these functional areas, indicating that the development mode of the residential areas is the loosest and has the lowest density, creating a pleasant living environment. The innovative villages are mostly located in the suburbs or on the edge of urban areas. Among the different types of functional areas, their block scale is the largest, but at the same time, their road network density is also the highest, thereby improving the connectivity and space of the parks.

Table 8.10 The urban gene bank

Indicators		Central areas	Residential areas	Innovation villages	Science parks
Block scale	Average	2.12 ha	3.18 ha	3.97 ha	1.60 ha
	Range	1.27–3.52 ha	1.04–7.50 ha	2.0–5.9 ha	1.19–2.00 ha
Road density	Average	3.65 km/km^2	3.27 km/km^2	5.12 km/km^2	3.69 km/km^2
	Range	2.04–5.04 km/km^2	1.69–7.10 km/km^2	4.26–5.98 km/km^2	3.20–4.18 km/km^2
Building density	Average	46%	34%	36%	37%
	Range	36–65%	25–52%	22–51%	29–44%
FAR	Average	2.03	–	–	–
	Range	1.6–2.8	–	–	–
Number of floors	Average	5.55	–	–	–
	Range	4.2–6.2	–	–	–

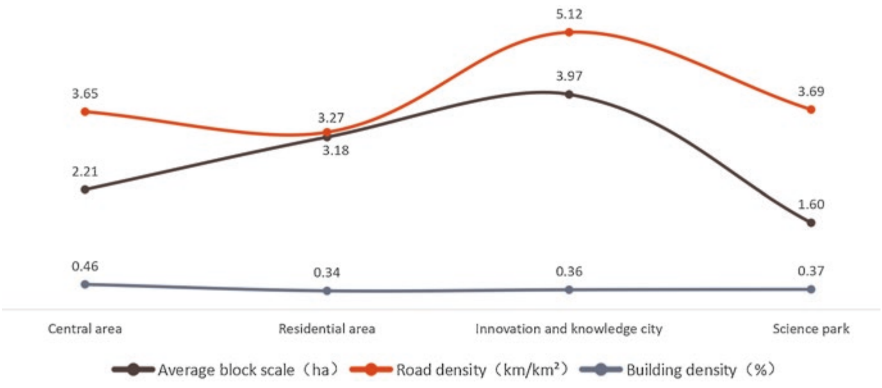


Fig. 8.9 The comparison of different urban functional areas

The results also imply that high-density and mixed-use functions are important elements for improving the vitality of space. However, the excessive pursuit of high-density construction can also have a negative influence. We can refer to the development modes and scales of these successful urban developments and apply them to the generation process of the spatial planning of the Xiong'an New Area (Table 8.10 and Fig. 8.9).

8.5 Conclusion and Discussion

8.5.1 Concluding Remarks

Based on the development strategy of building an ecological and technological city for the Xiong'an New Area, this research chooses a total of 30 areas with different urban functions as cases for the planning and construction of Xiong'an. Focusing on construction density, we calculate the average block scale, average road network density, average building density, average FAR, and average number of floors for each case. The urban spatial form gene bank of various functional areas is constructed by statistical methods.

This study shows that the spatial forms presented by these research cases in different locations and with different land uses are quite different. Overall, the urban central areas and science parks have similar spatial forms, preferring small-scale blocks, a high road network density, and a high building density. Specifically, the central city areas are mostly in small-scale blocks and have a dense road network, and high building density, especially the European old cities, the modern Chinese city centers, Singapore, and the US urban centers. The science parks are divided into those with a large scale and a low building density, represented by Caohejing and Shanghai, and those with small-scale blocks and a high density, represented by Silicon Roundabout in London and Messestadt Riem in Germany.

Regarding the residential areas and innovative villages, their spatial forms are similar, with a larger block size and a lower building density than the central areas and science parks. Specifically, there are two different types of residential areas in terms of their spatial forms. One is represented by the new German district, which has a small block scale, dense road networks, and high-density residential areas. The other is represented by the Overseas Chinese Town in Shenzhen and the Swedish Eco-City, which have a large block scale and a low building density. Similarly, the innovative villages also present two different types of spatial forms. One is the university towns in the suburbs of the USA and Germany, which are mostly street scale and low density. The other is the university towns in the center of the USA, which present small-scale neighborhoods with high-density road networks and high-density buildings.

8.5.2 Discussion

This research provides rational and scientific support for the generation of spatial forms in the Xiong'an New Area urban design project by exploring quantitative case studies. However, there is no city that can be completely copied as a case for Xiong'an because there is no ecological city as large as it is on a physical scale. We can extract the most valuable elements in each case and design the Xiong'an New Area based on these current excellent cases. These urban spatial form genes draw on the most classic and cutting-edge planning experiences in the world and can provide planning standards for various functional areas. Based on the research methods borrowed from this case, we can map the future of Xiong'an with the status quo of advanced cities.

At the same time, we also notice that with technological progress, the lifestyle of human beings has undergone great changes. We cannot predict the impact of future technologies on the organization of human and urban space. As the "millennial plan" of China, the Xiong'an New Area has to be able to keep pace with the changes of the time during the construction process and be flexible for future adjustment.

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Part IV
Embracing Advanced Technologies and Transitioning of Cities into Better Designed Sites

Chapter 9
The Next Form of Human Settlement: A Design for Future Yilong City

Abstract As what we have described in Chap. 1, advances in ICTs (information and communication technologies) and intelligent manufacturing bring changes in daily life and urban space. A series of new technologies that have a disruptive impact on urban form, such as intelligent logistics, VR (virtual reality), AR (augmented reality), UAV (unmanned aerial vehicle), AI (artificial intelligence), and sharing economies, are gradually reshaping our cities. This chapter embraces these emerging technologies and the trend of transitions in cities to create a future human settlement. This chapter reflects the core concept of the third type of data augmented design (DAD). In this chapter, technological changes and trends of thoughts related to urban development in the past three hundred years have been comprehensively summarized to help understand the impact of technologies upon cities. As a result, the important concept and core value of the human settlements are identified and classified. This design concept is applied in the Yilong New District of Guizhou Province, China. Considering its remarkable karst landform with eroded lava, a new agenda for the future human settlement is proposed with five levels of rules—the code (essential future development concept), the background (natural environment), the area (including "living area" and "entertainment area"), the system (cloud computing infrastructure systems, functional systems, and settlement systems), and the module (combining mobile module (functional cubes) and the fixed modules (Home, Hub)). It is expected to express the imagination of the future human settlement.

Keywords Future city · Urban evolution · Human settlement · Urban design · Artificial intelligence

Y. Long, E. Zhang, *Data Augmented Design*, Strategies for Sustainability,
https://doi.org/10.1007/978-3-030-49618-0_9

9.1 Introduction

Through reviewing the history of technological inventions that affected the form of human settlement, we gain insight into how upcoming new technologies will dramatically affect the future form of human settlement. As in the past, in the near future, human settlement will move from rural areas to urban areas and then further enter a new form. Moreover, in the era of globalization, the urbanization process is the focus of the next phase of balanced human settlement systems. The "Yilong Futuristic City International Design Competition" was held in 2017 and called for interesting ideas around the world on the futuristic city. This competition was hoped to spur the generation of new ideas on how to build a new modern urban life in a natural background and on the relationships between the local and the global, tradition and the future, the east and the west, the landscape and the city, nature and human habitation, protection and development, imagery and reality, etc.

This chapter, inspired by one awarded work in the competition, discusses the new form of human settlement, including a system that can integrate all the urban functions, the method that can be used to organize the built area, and the ideas that can be used to express a symbiotic relationship between the future city and emerging technologies. To better elaborate the design for Yilong, this chapter is organized as follows: first, through the literature review, the concept and the core value of human settlement are introduced, the critical elements that should be adopted in the further design are identified, and the map of related technologies and the related thought or theories is arranged to identify key inventions that have influenced human settlements. Second, a series of new agendas for design is created to show how the ideas outlined in the previous section are refined. Finally, based on information obtained on the competition website, the new agenda for design is further developed. In addition, we discuss the feasibility of the design for the next form of human settlement.

9.2 Literature Review

9.2.1 The Development of Human Settlements

Due to the rapid development of industrialization and urbanization, the large-scale agglomeration of industry and population, urban environmental pollution, ecological damage, and the health of residents are becoming increasingly serious. Determining how to coordinate the relationship with the living environment and economic development has become a prominent problem in the process of human settlement development. At present, the urban human settlement environment is one of the hotspots of architecture, geography, environment, planning, and other disciplines (Edward 2011).

Tracking back to the earliest discussion, the concept of "Ekistics" proposed by Constantinos Apostolos Doxiadis (1970) around the 1950s is one of the most well-known and systematic concepts. The word "ekistics" is derived from the Greek adjective οἰκιστικός, which means "concerning the foundation of a house, a habitation, a city or colony; contributing to the settling." Ekistics concerns the science of human settlements, including regions, cities, community planning, and dwelling design (Asher 1969). Ekistics involves every kind of human settlement but pays particular attention to geography, ecology, human psychology, anthropology, culture, politics, and occasionally, aesthetics (Doxiadis 1968).

Cities rely on the advance of related technologies and have become the dominant habitat of human beings. Human settlements have changed substantially. However, while the wave of urbanization is sweeping the world, an increasing number of problems, such as air pollution, water shortages, traffic congestion, and a deterioration in public security, are caused by rapid urbanization. Planners and urban residents are confused and ask the following questions: Can the city as a main settlement support people's simple and grand life ideals? What kind of settlement would be more flexible and sustainable?

9.2.2 *Map of the Technologies Influencing the Form of Human Settlement*

We reviewed almost all the techniques invented that have had a significant impact on human settlement since the 1700s and observed the evolution of human settlement over the past three centuries (Fig. 9.1). The results show that human beings have developed two typical types of human settlements, rural and urban. The maturity of the construction technology, the use of concrete, the emergence of elevators, and the popularity of vehicles have been used to make systems, such as the road network system. The height of buildings and construction density differ in rural and urban areas. Naturally, we can foresee that the development of a series of new technologies, such as autonomous vehicles, smart logistics, virtual reality (VR), unmanned aerial vehicles (UAVs), artificial intelligence, and sharing technology, which will have a tremendous impact on the form of human settlement, is rapidly

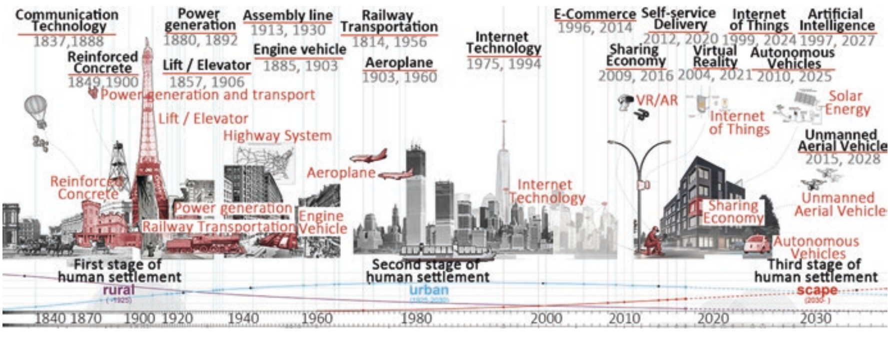

Fig. 9.1 The transformation of human settlements through emerging technologies

maturing, which will accelerate our progress towards the form of next human settlement. The following is a detailed introduction to several important inventions.

Through a review of the essential inventions that have influenced the form of human settlements, it is found that, specifically, the communication technology developed at the end of the nineteenth century made possible unlimited communication, and human society was able to rapidly expand the settlement environment. The technology of reinforced concrete allowed high-rise buildings and large-span bridges to be constructed and led the history of human architecture into a new era. Power generation and electricity transport technology advanced by Edison in the late nineteenth century defined the infrastructure of cities. Moreover, lift/elevator technology made skyscrapers possible, and skyscrapers became the symbol of the big cities in the second half of the twentieth century. The assembly line devised by Henry Ford in the twentieth century greatly accelerated industrial production and changed the places where people work.

The above technologies made horizontal and vertical extensions possible for urban areas. Since the end of the twentieth century, the development of the Internet has had various impacts on the form of urban areas. Subsequently, new concepts and technologies, including the sharing economy, smart retail, the Internet of Things, artificial intelligence, etc., have been developing at an expeditious rate and has caused the original urban spaces to be faced with unprecedented challenges. According to the Gartner Hype Cycle for emerging technologies (Fig. 9.2), basically, the development of technology has five stages: the innovation trigger, the peak of inflated expectations, the trough of disillusionment, the slope of enlightenment, and finally, plateau productivity. We reviewed inventions that deeply influenced the morphology of the habitat over 300 years based on the concept mentioned above and identified their invention time and mature period of popularization. The results are shown in a "map of technologies affecting human settlement" (Fig. 9.3).

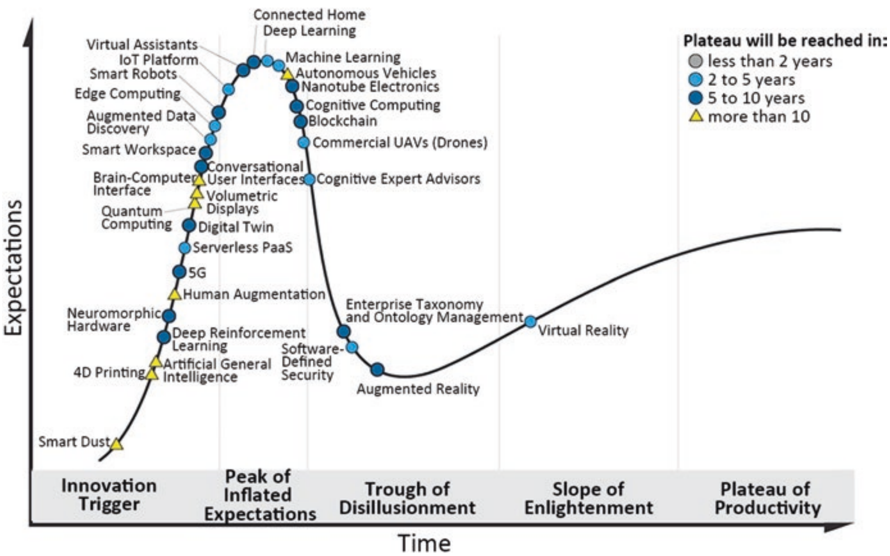

Fig. 9.2 Gartner Hype cycle for emerging technologies (Source: Gartner 2017)

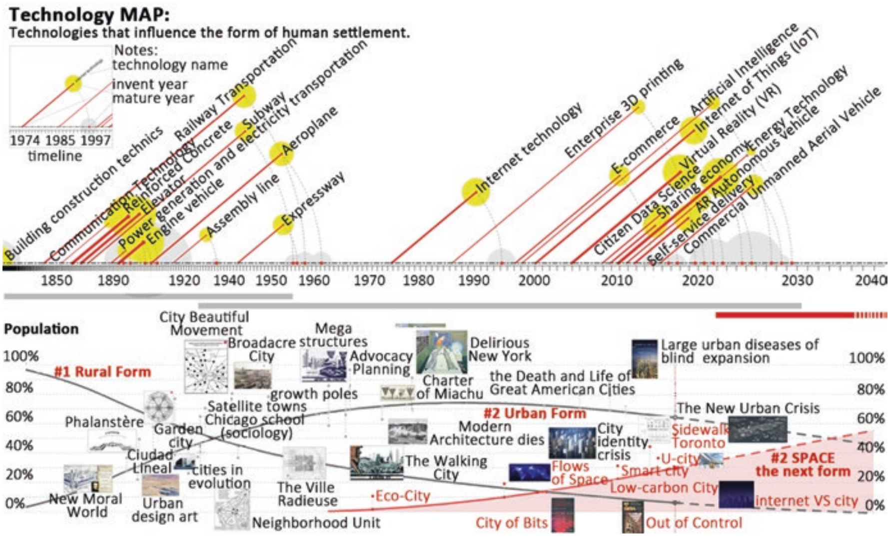

Fig. 9.3 Map of technologies affecting human settlement (top). Timeline of theories affecting human settlement (bottom)

9.2.3 Trends of Thoughts, Theories, and the Different Forms of Human Settlement

The trend of thoughts about cities has been updated as technology has changed (Fig. 9.3). For example, cities began to become significantly efficient in the early twentieth century; therefore, people began to focus on the rules of the new human settlements for the first time. A series of classical concepts, such as a garden city, an industrial city, a linear city, a broadacre city, and a gradient city, was born in that era.

Afterwards, in the 1950–1960s, as the basic form of human settlement was almost fixed, the trend was to praise the successes of cities and to discuss more details concerning the urban morphologies, human design (Jacobs 1961), and even the highly hailed skyscraper (Koolhaas 1978). However, in the past few years, with the increase in Internet development and the intellectual manufacturing revolution, planners and citizens obviously feel that cities lack efficiency and adaptability in terms of Internet access. Negative space, retail withering, and local cultural civilization crises began to occur in cities, which seems to no longer be a sustainable form for further human settlement (Kelly 1995). Many scholars began to focus on sustainable development, low carbon processes, and the relationship between the city and the Internet (Castells and Himanen 2003), and even think about the future urban form. This somehow indicates that the urban form revolution is taking place, and the next human settlement is coming.

9.3 The Design Framework

9.3.1 Design Site

The site of the competition is the Yilong New District, Guizhou Province, China. Founded in June 2013, Yilong New District is located in the center of Xingyi, Anlong, and Xingren counties. It is a commercial distribution center at the junction of the three provinces of Yunnan, Guangxi, and Guizhou (Fig. 9.4). There are two provincial-level economic development zones and nine towns with a land area of 258.5 km^2 and a planned control area of 236 km^2. The existing population is 339,600, and the predicted population is 800,000. Yilong New District is positioned as an international ecological smart city and a national new district with an output value of 100 billion yuan. The design site is located in a mountain region of Guizhou Province, China, which is now facing an economic recession. The investment in government construction in the new district could have a positive effect on the balanced development between the city and countryside. This process will make it possible to develop a sustainable relationship between the natural environment and human society development and the next form of future human settlement.

9.3.2 Design Concept

Yilong District is the most promising area in Guizhou, China, and its core area, Qiushui Lake, is facing a revolution in terms of urban design, which also creates an opportunity to build a futuristic city from scratch.[1] As the competition calls for interesting ideas for the futuristic city, considering advanced technologies and theories, we envisage that in the future, the human settlement environment will

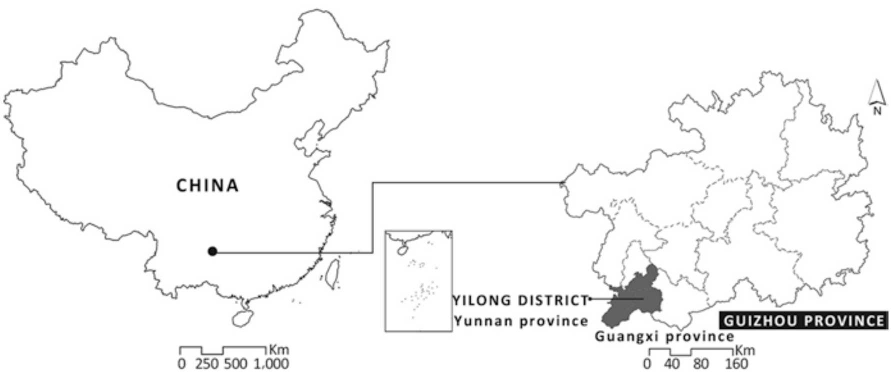

Fig. 9.4 The location of the design site

[1] Introduction to the Yilong futuristic city international design competition: http://futuristiccity.uedmagazine.net/en_index.html

respond to technology, and all functions can be carried out by drones and through unmanned driving. People will no longer need to move a large number of vehicles but will conduct their activities in standardized functional cubes, which are modular, have a variety of functions, and directly connect to the person's location. By considering the characteristics of both the region and the environment, a new set of rules for the future of human settlements is proposed. These rules include the code, the background, the area, the system, and the module. This design will reorganize the construction of human settlements through technological innovation, improve the efficiency of urban development, and simultaneously create more sustainable human settlements.

9.4 New Agenda for Design

9.4.1 Code

Under the background of the popularization and development of new technology, as well as the debate on the conflict between the protection of the natural environment and the development of human society, it is believed that the next form of the human settlement would be more flexible and intelligent. The following judgments are essential when discussing the future of human settlements:

Autonomous Vehicles will Evolve Into the Basic Functional Unit of Future Human Settlements, and People can Conduct Most of their Everyday Lives and Working Within Pedestrian Sphere

As self-driving vehicles begin to transform the way people move around, urban planners around the country are beginning to think about how they will remake cities and change the way we live. Many planners say they see an opportunity to prevent and correct the twentieth-century mistakes of the auto's reign: congestion, pollution, sprawl, and roads designed to move vehicles rather than people. At first, the car driver was liberated under the technology of autonomous vehicles, and then people will be in the automatic vehicle conducting other activities such as working, meeting, film-watching, entertainment, catering, and so on. Finally, these autonomous "boxes" will be a kind of "functional flow" containing aplenty of activities, which could be plug into people's home, drift on the plaza, or even just wander on the road. Based on these trends, people can embed functional streams (business, food, entertainment, clinics, education experts) into their residences. Embracing sophisticated logistics technology (takeaway, e-commerce express) and sophisticated VR technology (meeting, real-time interaction), most people can complete most of their living and working content in a limited space.

Digitally Driven Virtual and Real Environments will Support the Infrastructure of the Entire Human Settlement

As residential units become the smallest unit of human living, a large amount of space is released in the entire urban system. The entire urban system will become an infrastructure that serves human beings. UAV logistics systems, distributed warehousing systems, autonomous driving functions under cloud control, urban digital infrastructure in the cloud, and distributed energy supply systems will serve as a new infrastructure system for people.

The Space of Flows Becomes One of the Key Elements of Future Society

The space of flows is a high-level cultural abstraction of space and time and their dynamic interactions with digital age society. The concept was created by the sociologist and cybernetic culture theoretician Manuel Castells, which means "reconceptualizing new forms of spatial arrangements under the new technological paradigm," and a new type of space that allows distant synchronous, real-time interaction (Castells 1989). Castells then defined the specific concepts as follows: "the material arrangements that allow for simultaneity of social practices without territorial contiguity. It is made up first of all of a technological infrastructure of information systems, telecommunications, and transportation lines" (Castells and Himanen 2003).

The Importance of Ecosystems will Increase, and Ecological Experiences will Become an Important Way of Life for Human Beings

People will be aware of the scarcity and importance of natural ecology. The ecosystem will infiltrate into the living space and become a new skeleton of the habitat. Therefore, people will tend to engage in more experiential activities that could contact the natural environment, such as camping and cycling mountain climbing. These would become one of the most important human leisure modes.

9.4.2 Background

Future human settlements should be able to respect the natural environment and primitive humanities, and the ecological environment outside the scope of human settlements should reduce artificial construction and activities as much as possible. Therefore, the base of the human settlement environment must be considered with the natural environment in a large proportion. Through the preservation of the natural environment, the ecological environment that needs to be preserved is defined, as well as the scope of the living environment, and the encroachment and cracking of the natural environment are reduced (Fig. 9.5). This concept would also help retain more priority for the local ecological landscape, cultural landscape, and historical features to ensure that there is more space to conserve and preserve the unique style and temperament of the field.

9.4.3 Area

Due to the development of technologies such as unmanned vehicles, drones, and information communication networks in the future, many previous classification methods and boundaries of functions will gradually become blurred, and the areas of human settlements should be redefined, no longer like existing cities. Settlement areas will be divided into simple residential areas, business areas, commercial areas, etc., but will be based on a more flexible and floating classification. Therefore, this design proposes a floating area classification based on "function ratio" and "privacy level." The design is not rigid and fixed but may be subject to changes because the modules can change over time and accommodate various space conditions. People can define the state for a certain time period, and the settlement has three parts: the abovementioned "natural area," which has been defined as being in the background, and the "living area" and "entertainment area," which can contain the rest of the construction area (Fig. 9.6). Specifically, if the area needs to be more private, there are modules that can be used for residential services, such as residential, office, and other modules, which can be considered as "living areas." This type of area can be

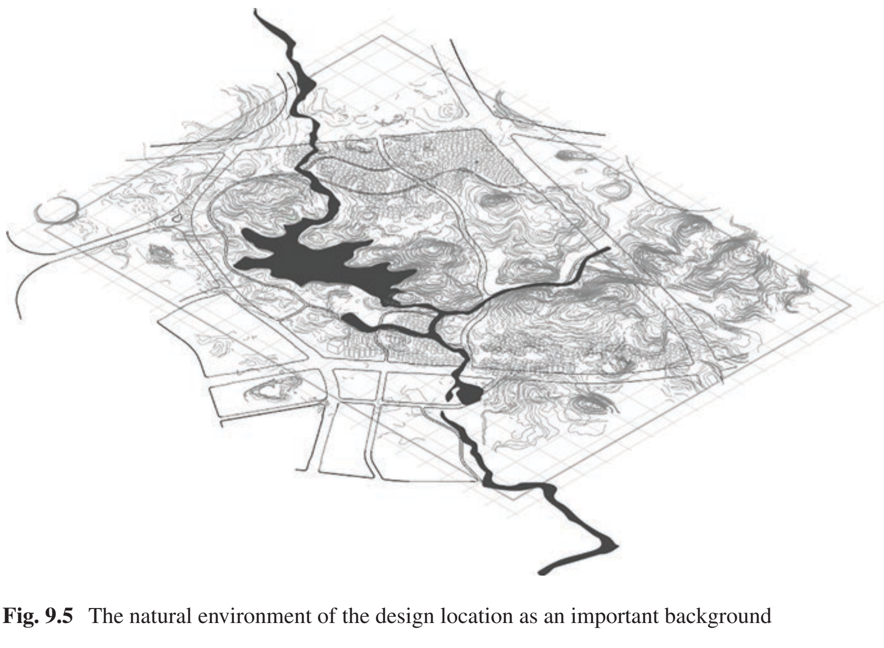

Fig. 9.5 The natural environment of the design location as an important background

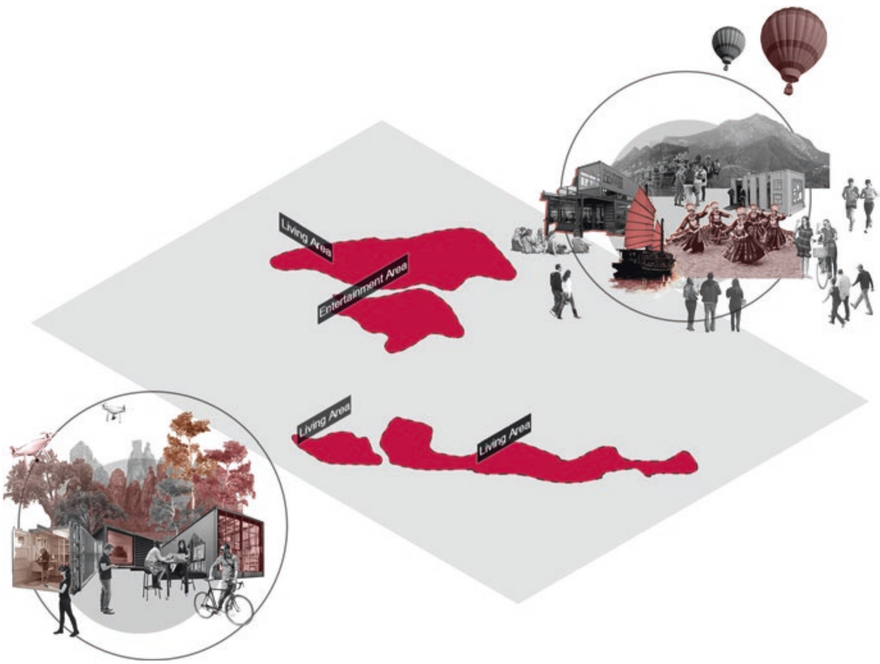

Fig. 9.6 Three types of areas defined by their function ratio and privacy level

used for various functions, such as general life, a residence, an office, and other functions. If there are many public modules, such as leisure and public office modules, the building modules or spatial patterns of this area will be more open, allow for more face-to-face interaction, and be more recreational; therefore, it is defined as an "entertainment area." The services that can be provided in this area will mainly be entertainment, leisure, catering, and other functions.

9.4.4 System

Due to the development of this design, it is believed that the mobility of urban space in the future will become increasingly obvious, so a system framework is needed to organize the flow space. Therefore, in this new form of human settlement, systems use a formula in which all kinds of modules are embedded, including cloud computing infrastructure systems, functional systems, and settlement systems (Fig. 9.7).

The cloud computing infrastructure system provides the most basic support and improves the living environment through a more efficient use of space that effectively reduces the size of dwellings. The future human settlement will be connected by ubiquitous smart sensors through the Internet to realize a comprehensive perception of the real environment. In this system, intelligent processing technology is

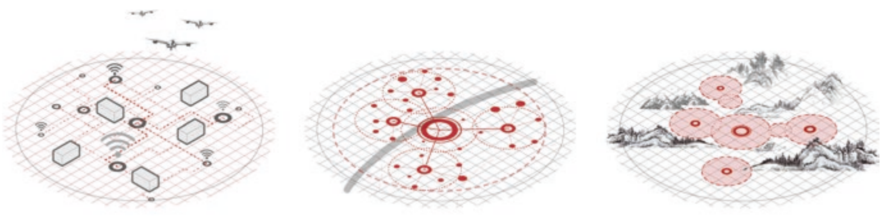

Fig. 9.7 System is a formula for arranging module, including cloud computing infrastructure system, functional system, and settlement system

used to process and analyze massive sensing information and discover objective laws, including government affairs, people's livelihood, transportation, and public issues. The intelligent response and decision based on the technology will also support various needs, such as security. In this way, the cloud computing infrastructure system can be regarded as a complex system with multiple applications and multiple industries. This system can implement information interaction and sharing and jointly extract data for comprehensive calculation and present calculation results. To fundamentally support the safe operation of this system, a cloud-based network should be installed in architectures.

The functional system is responsible for arranging and shipping all functional cubes (the detailed idea is discussed in the next section) to ensure that the functional modules of the human environment operate smoothly.

The settlement environment system is established based on the current human society, which can be divided into four layers, namely community, district, town, and big city. This system is suitable for a better resource allocation system.

These three systems interact with each other in this design. Specifically, the cloud computing infrastructure system supports the operation of the functional flow system, while the functional flow system further defines the hierarchy of the human settlement system.

9.4.5 Module

We assume that in the future, the living environment supported by new technologies such as UAVs and IoTs (Internet of things) will be more flexible and humanity. To achieve this, we design two types of modules: the mobile module and the fixed module (Fig. 9.8). Instead of those vehicles we use now, such as cars and trains, mobile modules with various functions would be the main tools that both contain plenty of activities and take people wherever they want to go. A series of standardized and detachable functional cubes are designed to carry these functions. These mobile functional cubes can carry functions required by daily life, such as bedrooms, bathrooms, restaurants, kitchens, etc. and other functions containing leisure

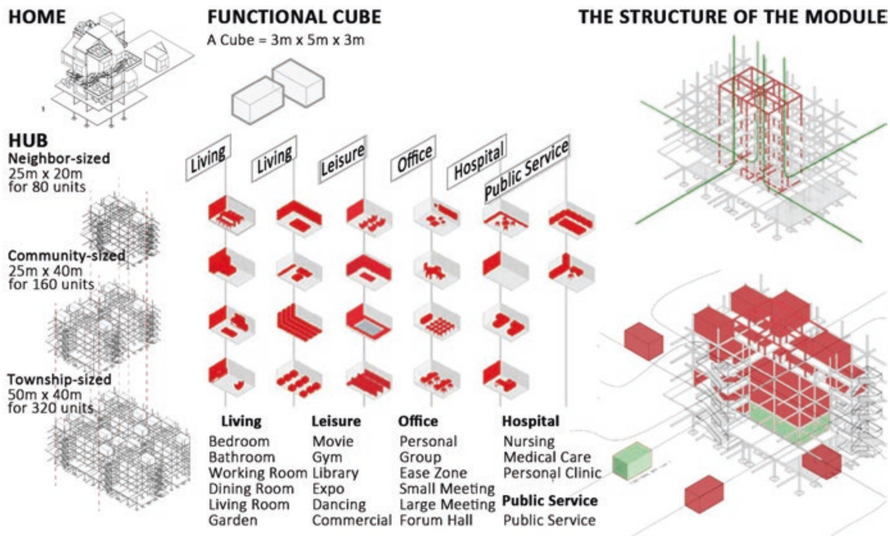

Fig. 9.8 Form, classification, and structure of the modules

activities, such as theaters, cafes, exhibition venues, libraries, etc. The latter type, the fixed module, is actually the collection center of the mobile module, which can be divided into home and hub according to the degree of privacy. Home is a collection center for families and individuals. It is a living type of functional cube that will gather together to form a living space that meets different family units and customers. Hub can be divided into different levels according to the service radius. Generally, smaller community units will correspond to smaller Hubs. Conversely, larger areas will have larger hubs to serve human society better and more efficiently.

Combining the mobile module (functional cubes) and the fixed modules (Home, Hub), the human settlement environment is flexible to meet the needs of human society, reducing the waste of space resources.

9.5 Design in Detail

9.5.1 Design Generation

Characteristics and Potential of the Site

The Yilong New District is surrounded by the remarkable karst landform, with eroded lava, a humid climate, an eroded landform, and complex groundwater tunnels and is subject to soil erosion and rocky desertification. Due to the increasing development intensity of human beings, construction land expansion is urgently needed. The pressure of cultivated land protection is great, and the contradiction between people and land is particularly prominent. The design site is a typical ecologically sensitive and vulnerable area. The hinterland of the southwest, the mountains and rivers, the coexistence of multiple cultures, and the geographical location of southwestern Yunnan make this area unique when discussing the frontier and inland areas. Today, this area is faced with the change from a closed city that belonged to the agricultural era to a new global era. The original ecological scenery, the localized ethnic customs, and the diversified southwestern area face urban development under the trend of globalization. In summary, Yilong New District is one of the most promising new districts in southern China and provides the opportunity to build a new form of human settlement with sustainable and flexible design to face future challenges in the new era.

Local Landscape and Future Form of Human Settlement

The mountains and rivers surrounding the Yilong New District have their unique "regional character" from natural erosion and dissolving limestone, which provides abundant materials to discuss the relationship between the pressure on the preservation of typical agricultural land and the development of urban construction, as well as the ancient landscapes and modern lifestyles. The landscape culture system is once believed to be a network of meanings that Chinese people practice for the traditional space of mountain habitats. The value of contemporary space practice is reflected in the traditional Chinese sense of security, belonging, comfort, pleasure, and history based on various means of modern space creation and a series of aesthetic activities, ethical activities, and philosophical activities.

Customized Module Designed for Local Conditions

As the mountain is a major feature of the Guizhou region, traditional local buildings will "grow" in terms of geographical and hydrological differences, forming a unique geographical and cultural landscape. In this design, we use "sloping roofs" and "modularization" to adopt to the space and deepen the design to form the unique local image of "karst topography" in Guizhou. Specifically, prefabricated buildings will be rationally metabolized and converted according to the different needs of different periods, including the transformation methods of plugin, extract, subtract, etc., and combined with the overhead frame structure (Fig. 9.9). The hollow frame is mainly used to connect functional cubes from different places, allowing each building unit to integrate with the overall living environment system (Fig. 9.10). For example, homes will be constructed using more functional modules, such as rooms, living rooms, and kitchens, and hubs will connect more entertainment modules, such as coworking offices, libraries, and theaters, that will be used by the public. This design is expected to help protect the national culture and environment while meeting the needs of human society.

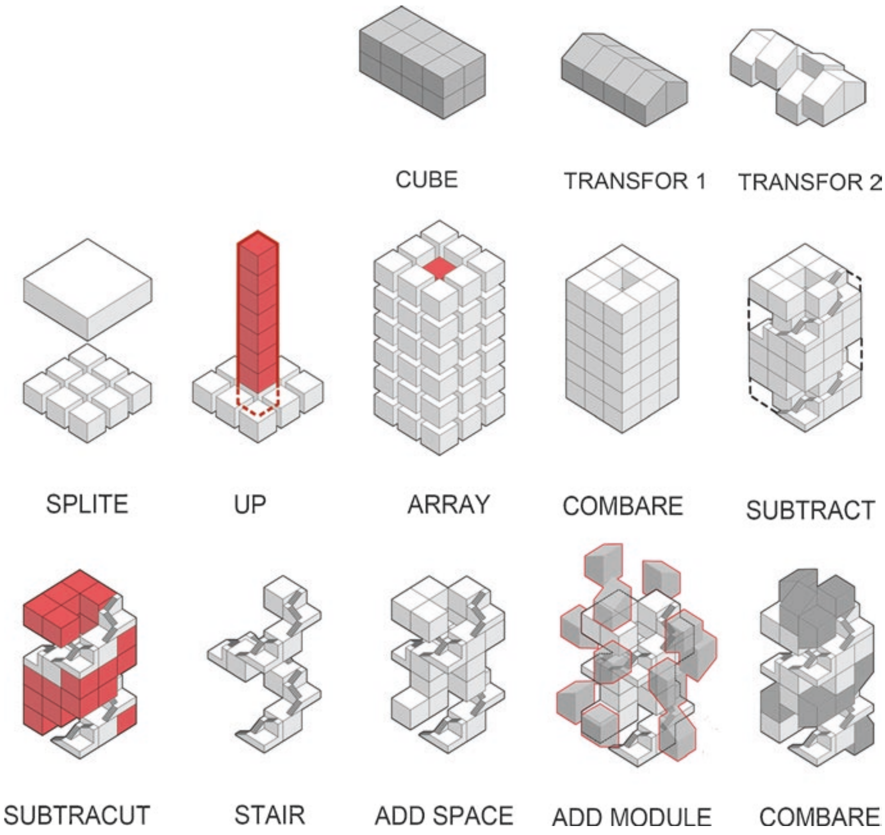

Fig. 9.9 The transformation methods used for the modules

Location Decision of the Functional System Node

The rich terrain characteristics and the lake in the middle make the target site a very pleasant and unique place. This design draws on these features, taking the highway road around the site as the boundary and using a main road throughout the base as the central spine of the area. The different levels of the modules are arranged separately to organize the function flow and operation mode of the whole site. The design considers the environmental characteristics and the existing topography in the selection of three large hubs inside the site, corresponding to the three major areas.

9.5.2 Design Layout

Based on the generation of the design elements above and the analysis of the existing conditions of the site, the practical planning of the Yilong New District of Guizhou used for the proposed design will involve three steps. First, the natural area

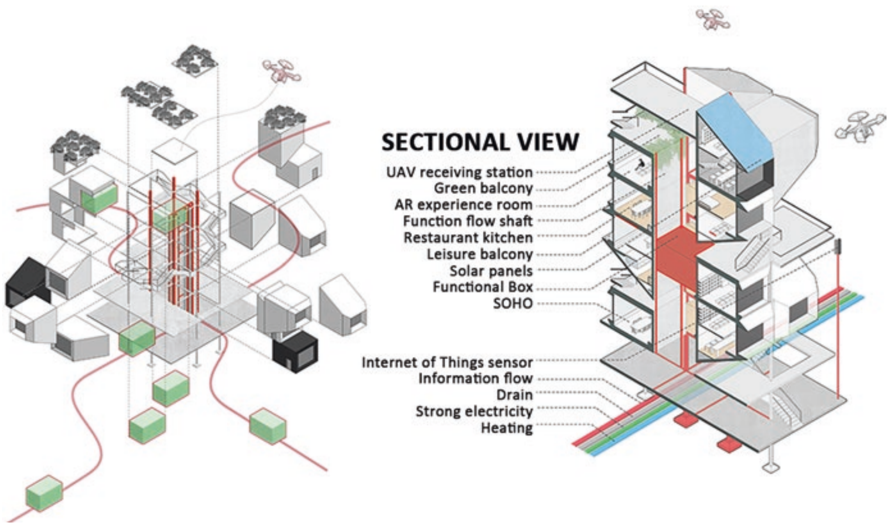

Fig. 9.10 Module combination method and the section of an example

and the living environment area were delineated to maximize the protection of the natural environment. Then, according to the condition of the site, different types of systems are laid out. The settlement system will be distributed according to the geographical conditions, while the functional system and the cloud computing infrastructure system will be further organized. Finally, building modules are designed and set according to the characteristics of the site. These steps make the whole area more organic and environmentally friendly (Figs. 9.11 and 9.12). This process is expected to enhance the achievement of the comprehensive goals of reducing living space, saving time and resources, and providing a greater proportion of and better access to nature (Fig. 9.13).

9.6 Conclusions

This chapter discusses the third type of applications in DAD, which fully embraces advanced technologies and helps cities better transition to improved sites. The history of technologies and their great impact on human settlement are reviewed, and thus, an illustration of the trend of the technology-based transition of human settlement is provided. As the design site Yilong is expected to become a futuristic city, the proposed design fully takes advantage of its unique landscape and develops its next form by putting forward a new agenda, which includes five layers: the code, the background, the area, the system, and the module. This design is based on some emerging technologies, such as UAVs, prefabricated buildings, VR, and IoTs, and focuses on human settlement, which involves various types of activities, such as

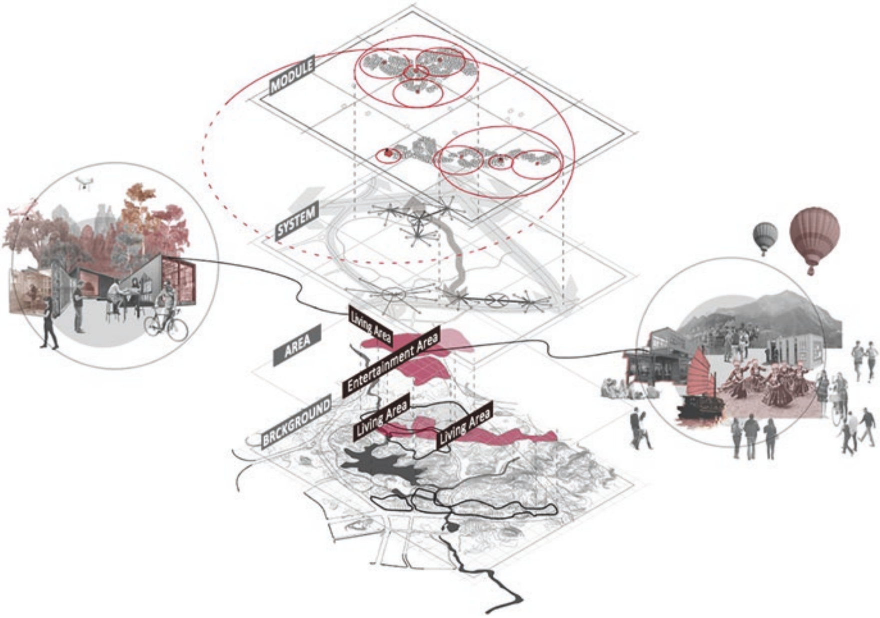

Fig. 9.11 The final design layout of the Yilong New District with four essential layers of the next form of human settlement

Fig. 9.12 The aerial view of Yilong New District

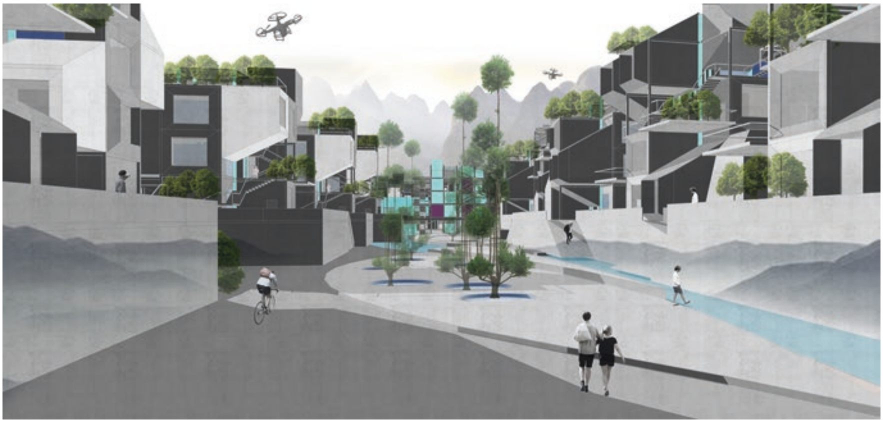

Fig. 9.13 Imaginary scene of the next form of human settlement

living, working, recreation, and transportation. Thus design applies new technologies, such as unmanned vehicles and drones, to the whole process to better shape a sustainable human settlement. A new form that involves organizing various functions influenced by emerging technologies is also introduced in this design, which reflects the core concept of the third application in DAD.

By introducing the design case in this chapter, we show the future-oriented design framework in DAD, which is different from the former two types, namely redevelopment-oriented DAD and expansion-oriented DAD. The third type fully embraces cutting-edge technologies to imagine future urban life and create future urban forms. However, this design is not meant to be pure fantasy but is based on emerging technologies that we can see or foresee in the near future. Urban life will be influenced by these technologies, some of which are reviewed in Chap. 1 and are already available and some of which we see through the lens of technology. In other words, rational ingenuity and thinking about future life and future space are important parts of DAD.

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Chapter 10
The Future of the Smart Island: A Design for a Natural and Technological Experience District on Huangguan Island

Abstract With the environmental improvement and smart city construction, the call for smart design has risen great attention. In addition to the future human settlement we interpret in Chap. 9, the new way for recreation and tourism needs also to be discussed. This chapter takes the Huangguan Island as the design site and combines the traditional spatial intervention and emerging digital innovation methods to design a smart island. Multi-sourced data is analyzed to reveal the present situation, existing resources, and advantages of island to help find out design strategies under the support of Data Augmented Design (DAD). Based on this analysis, a physical ring called smart "O" is constructed to connect the Huangguan Island with surrounding areas, regarding them an integrated district. Then, involved with various sensors and AI (Artificial Intelligence) technologies, four aspects of strategies and four systems are proposed to explain how to build a "scientific and technological natural experience" in the physical space. Eventually, the "O" ring contains various functions such as monitoring, transportation, and information with the version of "online and offline interaction" and "virtual and realistic experience."

Keywords Smart city · Urban design · Digital innovation · Artificial intelligence · Place making

10.1 Introduction

New developments in technology and science have drawn substantial attention worldwide since the last century and motivated designers and researchers to investigate the potential of applying new devices and techniques to change people's lives and environments. With the wide diffusion of the concepts of the digital city and the smart city (Dameri 2013), in addition to governments and organizations, planners and designers have also realized that tremendous advances will result from new technologies. The smart city includes many aspects, such as natural resources and

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energy, transport and mobility, buildings, living, government, the economy, and people (Neirotti et al. 2014). Worldwide, most metropolises, including London, New York, Seoul, and Tokyo, have already created strategies for the development of smart cities. In China, The Ministry of Housing and Urban-Rural Development (2012) issued the “Notice for the Pilot Work on National Smart Cities” in 2012, making the smart city a goal for many cities, such as Beijing, Shanghai, Guangzhou, and Shenzhen. The aim is to apply various technologies to help solve urban problems, including traffic congestion, health care problems, and imbalances in the educational system. However, although current research has promoted the development of smart cities, more methods and theories are required if we are to generate a comprehensive understanding of cities (Batty 2013) and to lift them to a higher level—the smart stage. As a result, several competitions have been held in the context of the smart city to investigate the application of technology in the urban space.

A competition workshop entitled the “Future of the Smart Island” was held by the Chinese Society for Urban Studies, Spatial Planning and Sustainable Development from 8 Aug to 15 Aug, 2018. The workshop aimed to find new ideas and designs for Huangguan Island that could help transform it into a digital island with low energy consumption and self-sufficiency. The object of this design, Huangguan Island, is on the list of the first group of uninhabited Chinese islands, issued in 2011. The island is as small as a park, measuring approximately 500 × 500 m. During the competition, all participants were requested to live and work on the island so as to better experience it. The participants were encouraged to study, innovate, and design independently and spontaneously while considering current natural circumstances and the future development of urban areas. Additionally, generating ideas regarding nature and human construction activities was encouraged, including the future intelligent and digital construction of the island (Fig. 10.1).

This chapter describes one awarded work as a means to discuss how data augmented design (DAD) can be applied to the process of future-oriented design. The investigation is organized as follows. First, a basic analysis of the site was conducted to generate a design concept. Then, the overall design framework was proposed. In the next step, data analysis was performed to help better understand the site, particularly the island’s natural environment. Based on the analysis results, a

Fig. 10.1 Future of nature and technology

comprehensive system was designed that represents our vision for the site. A conclusion and discussion of the third type of DAD are presented in the last section.

10.2 Basic Analysis of the Site

10.2.1 Design Site

Huangguan Island is located in the easternmost part of China and is part of the county-level city of Fuqing, Fuzhou City, Fujian Province. Fujian Province, which is located on China's southeastern coast, is adjacent to Zhejiang Province, Jiangxi Province, and Guangdong Province and southeast of the Taiwan Strait and Taiwan Province (Fig. 10.2). Most of the Fujian land is covered by continuous mountains, hills, and intersecting valleys and basins, which account for more than 80% of the province's total area. The land coastline is tortuous and eroding, and its total length extends 3752 km. The intertidal zone has an area of approximately 200,000 hectares, with mud, sediment or sand as the main sediment. Fuzhou City is the capital of Fujian Province. It is the political, cultural, and transportation center of Fujian Province and a central city in the economic zone on the west side of the Strait. Fuzhou has a total area of 119,900 km^2 and a total coastline of 1137 km^2, accounting for one-third of the total coastline of Fujian Province. Administered by Fuzhou City, Fuqing City is a county-level city with 212 islands and 61,000 hectares of beach, which indicates the varied topography of the seaside area (Fig. 10.3).

Close to Huangguan Island, Dongbi Island is east of Fuqing City. Its length from north and south is 3.88 km, and its entire area is 2.64 km^2. Dongbi Island Tourist Resort is a coastal tourist resort offering unique characteristics and amusements by integrating leisure, sea sports, folk experience, seaside dining, beach bathing, and other functions. However, although Huangguan and Dongbi are only some hundreds of meters distant from one another, there is no ferry between them. If tourists

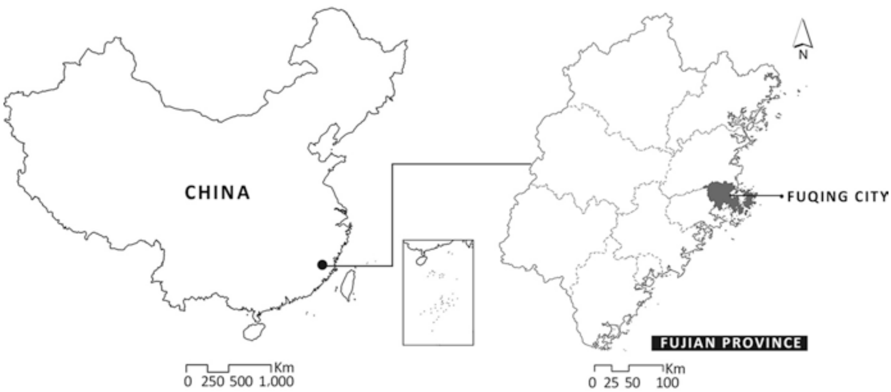

Fig. 10.2 Design site location

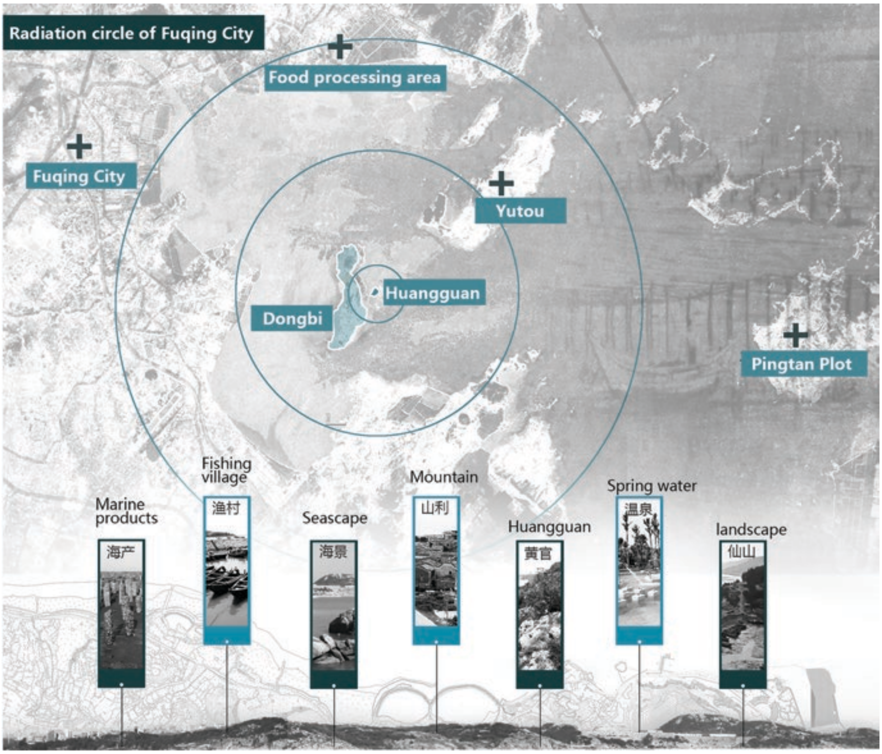

Fig. 10.3 City radiation circle

wish to visit the other island, the only option is to hire a small fishing boat or walk across the tidal flat after ebb tide. Overall, the merits of the resources of Dongbi Island have not been fully investigated.

10.2.2 Site Development Site

Because of its location and small area, information on the history of Huangguan Island is limited. However, the history of its neighboring island, Dongbi, can be traced to the Ming Dynasty. As noted in the Working Program of the National Strategic Construction of "Fuzhou on the Sea" issued by the local Municipal Party Committee and the Municipal Government, in the course of the development of modern and contemporary China, Huangguan Island and other uninhabited islands were designated for priority development. Subsequently, increasing attention was paid to promoting construction on four such islands in Fuqing. Since 2013, with the support of the local government, a yacht wharf and a wooden trestle road around the island have been completed to complement the existing transportation facilities, and

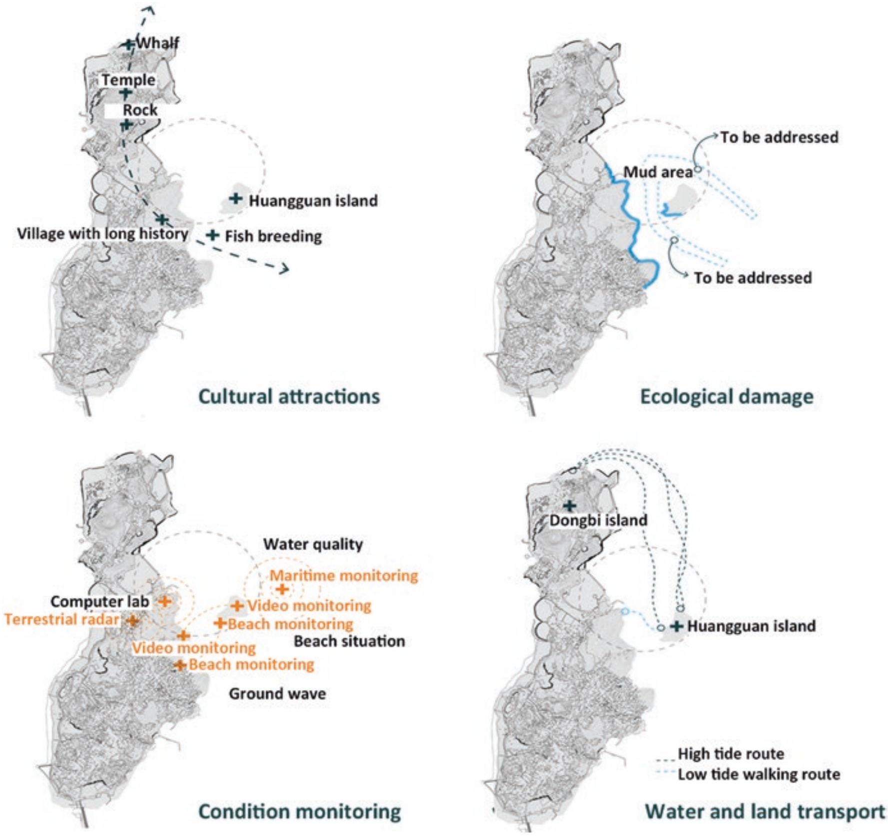

Fig. 10.4 Current situation of Huangguan Island

a leisure restaurant, wooden residential villas, and other facilities have been constructed (Fig. 10.4). To protect the island's ecological environment, water is not supplied by drilled wells but piped from the nearly mainland. Since the construction of reservoirs on the island, daily water has been supplied from the main island, while electricity is supplied by submarine cables to the uninhabited island. In last 10 years, all infrastructure construction on Huangguan Island has been complete. Recently, tourism has become Dongbi Island's primary source of external resources. Most people come to the island for holidays or special events, such as weddings.

10.2.3 SWOT Analysis

To better compare the site's advantages and disadvantages, we conducted a strength, weakness, opportunity, and threat (SWOT) analysis to assess the island's resources and to determine the potential and future opportunities based on government policy, resources in the surrounding area, and potential undesirable effects. The results indicate that the sparse ecologically friendly environment and rich marine resources of the island make it unique compared to other excessively overdeveloped islands. In addition, the island's location at the center of Fuqing Bay and its close proximity to several ports make it competitive. These observations indicate that the original ecological environment and the special location are vital advantages for Huangguan Island. In contrast, the size and terrain of the island are its primary limiting factors. Most of the island is covered by rocks, which means there is very little usable land. As a result of these constraints, the carrying and reception capacity of the island is limited. The best chance for the future development of the island is governmental support to develop smart islands in Fujian, which would make access to improvements on surrounding islands easier. However, the dilemma would remain of constructing a smart island while maintaining a balance between the new infrastructure and a healthy environment. It is worthwhile considering how to reduce the negative effects of tourism and construction.

10.2.4 Policy Support for Future Development

In 2010, Fujian's government published a new policy named "Digital Fujian," which encourages constructing a digital, networked, visualized, and intelligent system to integrate and cope with urban information in Fujian Province, with the goal of constructing a smart city system. This smart and digital system would integrate and utilize all types of information source to the greatest extent through digitalization and computer processing in all fields and would provide diverse information services quickly, completely, and conveniently to realize the informatization of the economy and society. The main content of "Digital Fujian" addresses the following aspects: strengthening the information infrastructure; expanding the use of the Internet and improving the public information network; promoting the integration of telecommunications, cable television and computer networks; and finally, realizing the interconnection and interoperability of various information networks to form an information-sharing system covering the entire province. Other aspects of this policy statement include enhancing the development and integration of various information resources, establishing a "Digital Fujian" technical support system, promoting industrialization by information, developing e-government, and promoting the construction of a government information system. The development and construction of information application systems represents the key strategy.

In response to this opportunity, local governments are paying substantial attention to the development of all districts in Fujian but particularly to new and coastline areas, which can accommodate more new changes. For Huangguan Island, this is the best time to think about the future.

10.3 Research Framework

10.3.1 Design Concept

The aim of this design consideration is to seek an appropriate way to develop Huangguan Island scientifically and sustainably. Regarding the smart city concept, the design aims to not only satisfy the demand for economical and efficient tourism but also the demand for ecologically friendly environment protection with rational technical support and creative strategies. The most important task is to develop methods to integrate the key factors of nature (i.e., landscape and marine resources) and human needs (i.e., hospitality and tourism experiences) and to enable future techniques to be applied in the design. In our opinion, spatial intervention is not the only way to design the site. In addition, by embracing new technologies, digital innovation represents another, essential way to create a space in a given location in the future (Fig. 10.5). That is, we can strengthen people's experience of nature and their perception of space using various technologies. Although this concept involves a future vision of design, one can nevertheless offer a detailed description and emphasize the approach's substantial potential to realize ambitious ideas.

10.3.2 Design Framework

Adopting the concept of spatial intervention and digital innovation (SIDI), this design is a research-oriented one based on the data augmented design (DAD) framework (Long and Shen, 2015). According to DAD, which serves as a foundation to help understand the actual site and generate strategies, we proposed a five-step design framework (Fig. 10.6).

First, to depict the site, we collected multiple data, such as geographic urban data for spatial analysis, meteorological data based on Ecotect (software specially

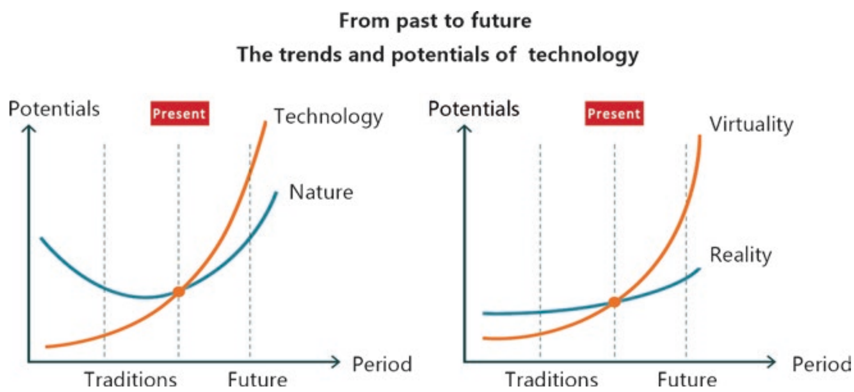

Fig. 10.5 Future vision of design

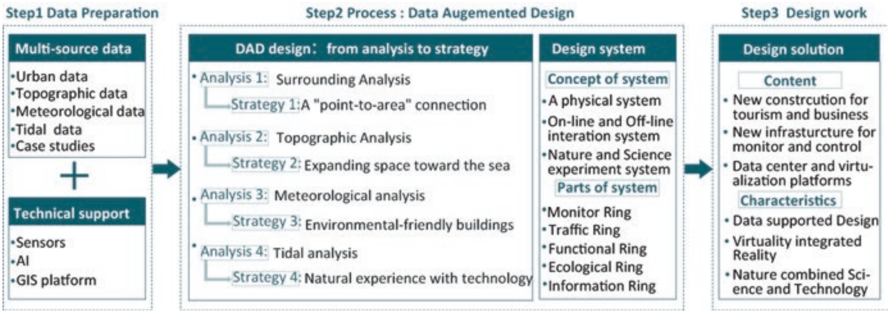

Fig. 10.6 Design framework

designed for analyzing the thermal environment), and image data. These data were analyzed to summarize current circumstances and locate any problems the site may have. Specifically, we used urban data, such as point of interest (POI) data, and road network data for Fuqing City and Changle City to describe the development condition of the site. We also searched for meteorological data in The Chinese Standard Weather Data (CSWD), meteorological parameters, and tidal information data to describe the actual environment. In addition, terrain data, such as contour lines and slope data, were collected, and a 3D model was created as the basis of the design. To better design the site, several case studies were conducted and their results collected as an important data source. Second, we chose several easily operated technologies to speed the process of data analysis and design generation. There are several such accessible tools, including the GIS platform for spatial analysis, sensors for data collection at the site, and artificial intelligence (AI), which were used for data analysis and design. The third step was the main part, in which we applied the data analysis results to generate the design. In this step, which was inspired by several conclusions based on the data analysis, strategies were proposed to enhance the design concept with creative and active thinking about technology application. These detailed designs for location and form are expected to solve specific problems. Based on these strategies, we established a comprehensive system from different perspectives for the design. The design integrates various functions, such as transportation, monitoring, ecological measures, and information gathering, as system activities. Finally, we present the future vision of the design using several sketches and scene graphs and explain our concept through specific designs.

10.4 Data Analysis for Understanding the Site

Data analysis, which provided comprehensive information for better understanding the site, is the crucial part of the research-oriented design. Such analysis can provide a solid foundation and rational explanation for underlying design strategies. Instead of making a framework for all fields of quantitative analysis, we focused on several main indicators that could help extract site features and identify prominent problems. However, data collection was difficult in this long-uninhabited location, which limited our research and analysis. Thus, we determined to analyze regional development rather than only the island. Based on the previous SWOT analysis, the natural environment has great potential to make the island better. Therefore, we analyzed the surroundings and several ecological elements, including topography, tide rules, and meteorology.

10.4.1 Surrounding Development Analysis

First, we studied possible impacts of urban development and future expansion on the island by analyzing the urban land, activity, the road network, development and construction around Huangguan Island using a GIS platform (Fig. 10.7). Because of the central location of Huangguan Island in Fuqing Bay, we selected the entire area around the bay. The results indicate that with urbanization, the commercial area around Fuqing Bay and in the Pingtan area has been growing in the last 5 years. Both the density of the urban road network and the urban land use scale have increased. Regarding Huangguan Island, although it lacks a rich material environment, the island's unique geographical position could facilitate using surrounding resources to help itself broaden its development. Therefore, it was necessary to consider the connection of Huangguan Island with its surrounding areas rather than only focusing on the limited area of the island.

10.4.2 Topography Analysis

The analysis of the land situation and topography through a GIS model enabled us to understand the natural conditions and construction situation. The GIS model was used to analyze altitude, slope, and orientation (Fig. 10.8). The results reveal that

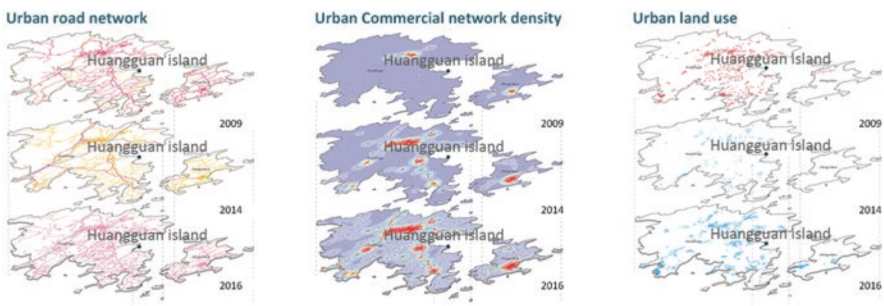

Fig. 10.7 Surroundings analysis

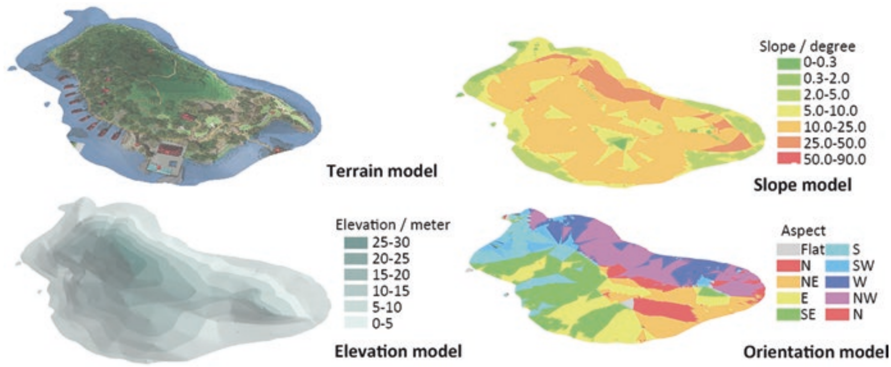

Fig. 10.8 Topography analysis

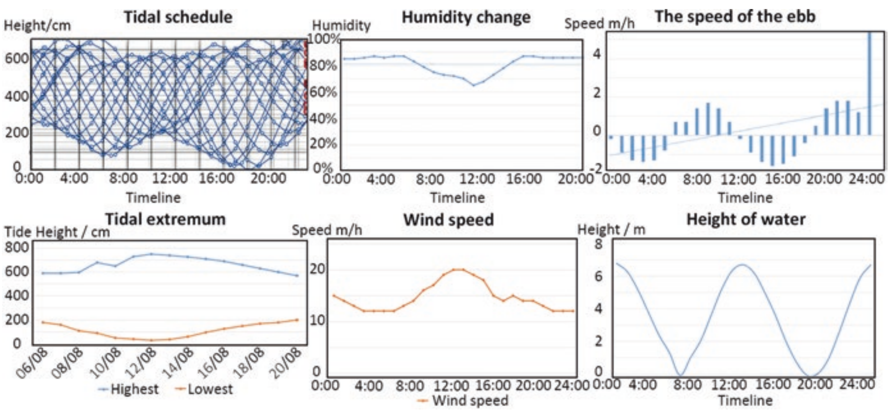

Fig. 10.9 Tide analysis

the island is covered by rock, and its slope is approximately 10–25°. According to the results, the northwest portion of the island is steeper than the southeast portion and thus not suitable for additional construction, while most areas in the southeast are covered by vegetation and offer a better landscape. These outcomes imply that the area for design and construction on the island is limited.

10.4.3 Tide Analysis

Because the island is surrounded by the sea, its landscape typically changes with the daily fluctuation of the tide (Fig. 10.9). According to data obtained from the local weather bureau, we present several graphs to describe the change of the waterline. The graphs indicate that the tide usually starts to rise at approximately 6:00 am and begins to ebb at 6:00 pm. During the day, the water level typically fluctuates between 6 m and 8 m, with highest level usually appearing between approximately 12:00 pm and 12:00 am. Such a spectacular natural tide phenomenon offers a unique opportunity for people to enjoy the charms of nature. In this design, the tide and beach landscape is considered in creating an attractive tourism area.

10.4.4 Meteorology Analysis

The purpose of analyzing meteorology and simulating a microenvironment was to seek a harmonious relation between the natural environment and buildings. The analysis of wind speed, temperature, humidity, and rainfall in all four seasons can provide a reference for the layout of buildings and their form. As shown in Fig. 10.10, the period from March to October is best for tourism because the overall environment is comfortable. Additionally, computational fluent data (CFD) analysis was applied to analyze the effects of different building layouts under the same wind condition to select the best layout.

10.5 System Design

The previously described comprehensive analysis of Huangguan Island represents a profile of this small island. However, when speaking of the future, two questions should be considered. What will the island mean to the region in the future, and what will the island look like in future? The first thing that concerns us is the relationship between the city, the island, and the sea (Fig. 10.11). In the past, people

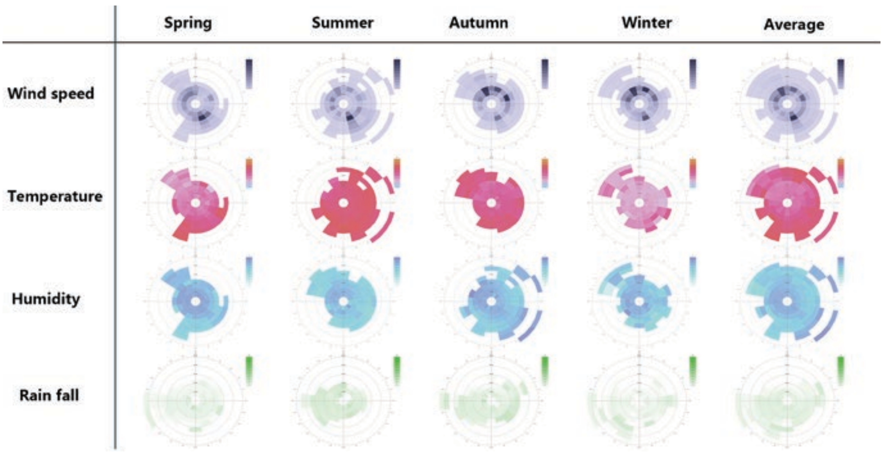

Fig. 10.10 Meteorology analysis

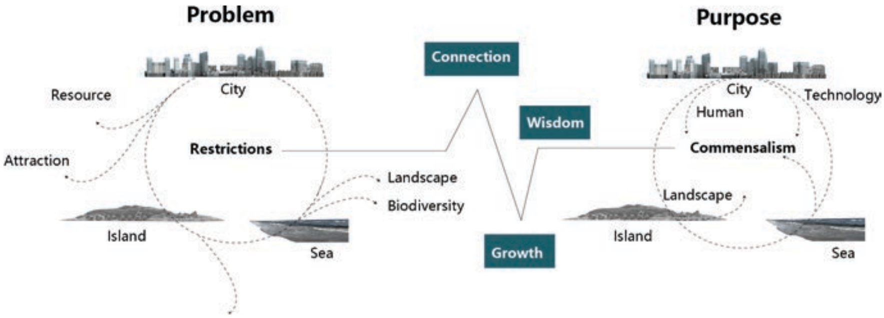

Fig. 10.11 System generation

lived in the city and easily found access to most of its resources, including technological offerings. However, because of its geographic isolation, few such resources could flow to island. Similarly, the natural landscape and ecological experiences are typically alien to urban residents. It seems that the "city-island-sea" relationship is weak and repulsive. To solve this problem, we aimed to design a carrier to connect the city and the island and bring more activities to the island. This technological carrier, which contains a series of functional systems, is termed the smart "O."

10.5.1 The Smart "O"

Considering the existing spatial location characteristics, we integrated all types of function in the carrier, which is also a carrier of science-technology-nature interaction and people-public space. We designed a physical ring named the smart "O" to reflect the connection between the former three components, which is coordinated with their distinct morphology and to present the three features of this design: "Obit," "Organic," and "Oasis." "Obit" means linking the island with the bay and city to change the situation of restriction and separation so that they can share resources and maintain a friendly relationship. "Organic" refers to constructing long-term sustainable development, which can be separated into several phrases so that new functions and facilities can be added gradually, decreasing their influence on the environment. "Oasis" contains the meanings of ecology and Utopia and expresses the aim of realizing a poetic habitation. Therefore, the smart "O" refers to employing new technologies and future life concepts in constructing a self-sufficient, environmentally friendly island, i.e., to create a unique future island (Fig. 10.12). In this design, embodying digitalization and technology in spatial design is the key point. Several strategies based on "connection," "growth," and "ecology" were developed to meet human demands and contribute to realizing a symbiosis between city and island as well as between human and nature.

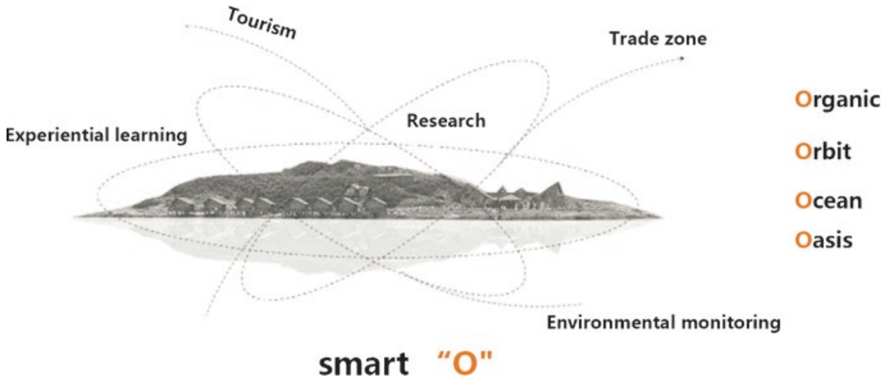

Fig. 10.12 Meaning of the smart "O"

10.5.2 Main Strategies

There are four main strategies that correspond to the core concept and the island's current problems: constructing a "point-to-area" connection, expanding the space toward the sea, coordinating buildings with their microenvironments, and embracing technology to augment reality. Aiming at solving the problem embodied in the analysis of the surrounding area, the first strategy is to solve the developmental problem on the city level. The second strategy addresses the land use problem and extends construction to the sea level. The third strategy considers the microenvironment and how to coordinate buildings with it, while the last strategy involves employing reality-augmentation technology to intensify the experience of nature.

Strategy 1: Constructing a "Point-to-Area" Connection

In view of the advantage of location, a connection strategy termed "point-to-area" was adopted to strengthen the connection between the island and the city by sharing culture, ecology, and resources and to assess the island's potential as the geographical center of Fuqing Bay based on lengthening the important loop to Fuqing City and Fuzhou City.

Strategy 2: Expanding the Space Toward the Sea

The extension strategy aims at expanding the island's available area, locating new construction in the seaside space, and joining it with island by the "O" ring to accommodate more functions. Considering the island's sustainable development in the future, the time dimension is considered. The construction condition is not static and can be adjusted according to actual use (Fig. 10.13).

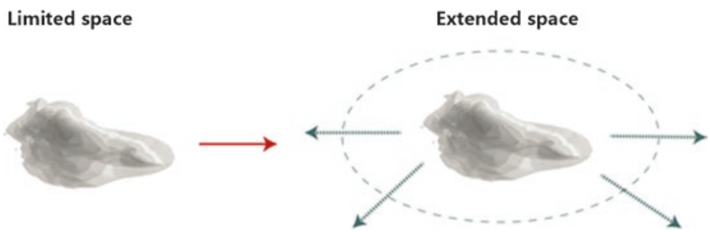

Fig. 10.13 Extension of the space

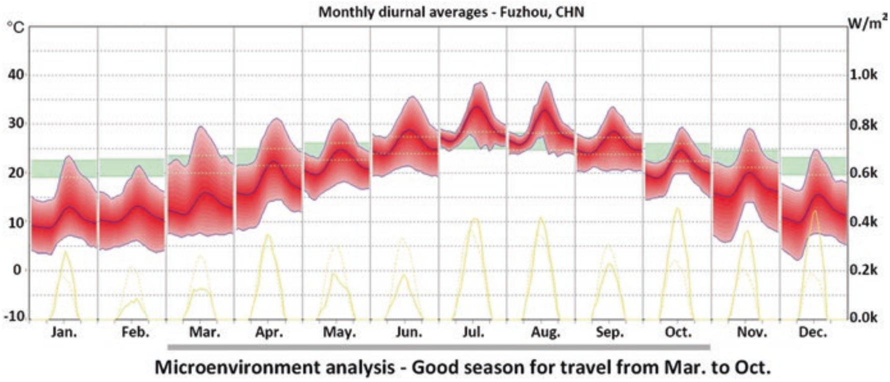

Fig. 10.14 Microenvironment simulation

Strategy 3: Coordinating Buildings with the Microenvironment

To create a more comfortable microenvironment, the environmental performance of various building layouts was simulated. As shown in Fig. 10.13, the courtyard-style building layout achieved better microenvironment simulation results (Fig. 10.14).

Strategy 4: Embracing New Technologies to Enhance the Experience of Nature

In view of the island's abundant landscape resources, the scenery near the beach represents a precious resource for experiencing closeness to nature. In this design, we attempt to make use of the change in tidal scenery over time and combine it with virtual reality technology to enhance the experience of reality and nature (Fig. 10.15).

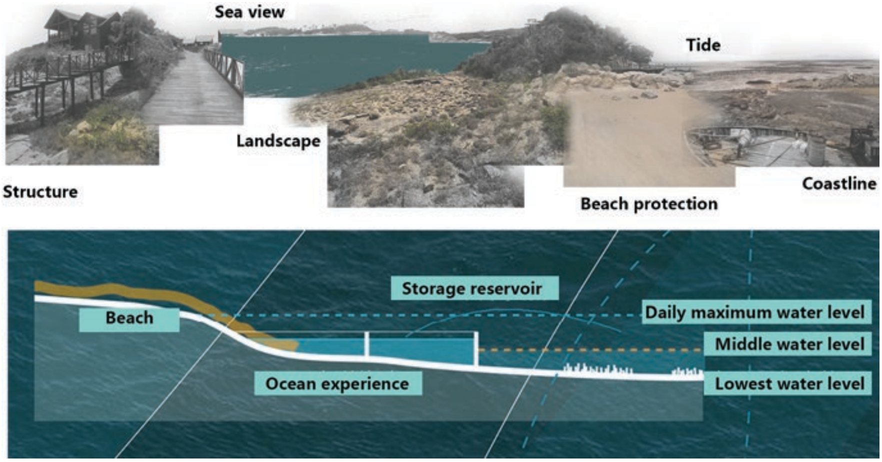

Fig. 10.15 Natural experience and ecology protection

10.5.3 Comprehensive System

Based on the described strategies, more detailed design aspects of the comprehensive system are discussed to clarify the design concept and realize the final version. The entire system is designed to address the traffic stream, functional distribution, the ecological experience, and information control. Therefore, four subsystems are involved: the traffic ring, the ecological ring, the functional ring, and the information ring.

System 1: Traffic Ring

The first function of the "O" ring is to organize traffic (Fig. 10.16). There will be a circular track on the surface of the "O" ring that will accommodate waterbuses and sightseeing trains. The "O" ring will also provide abundant paved walkways and bicycle paths for pedestrians and riders. As the main bridge between Huangguan Island and Dongbi Island, the ring will become the main way to enter Huangguan Island, supporting local delivery transportation and daily commuting (Fig. 10.17).

As shown in Fig. 10.18, two paths can be chosen: the ecological and technological experience route or the business and holiday experience route. The first route features a walking path in the tidal zone and access to a water experience, while the other leads people into the business and entertainment experience zones. In addition, there will be a port on the "O" ring with a waterbus wharf in the north and a yacht marina in the south.

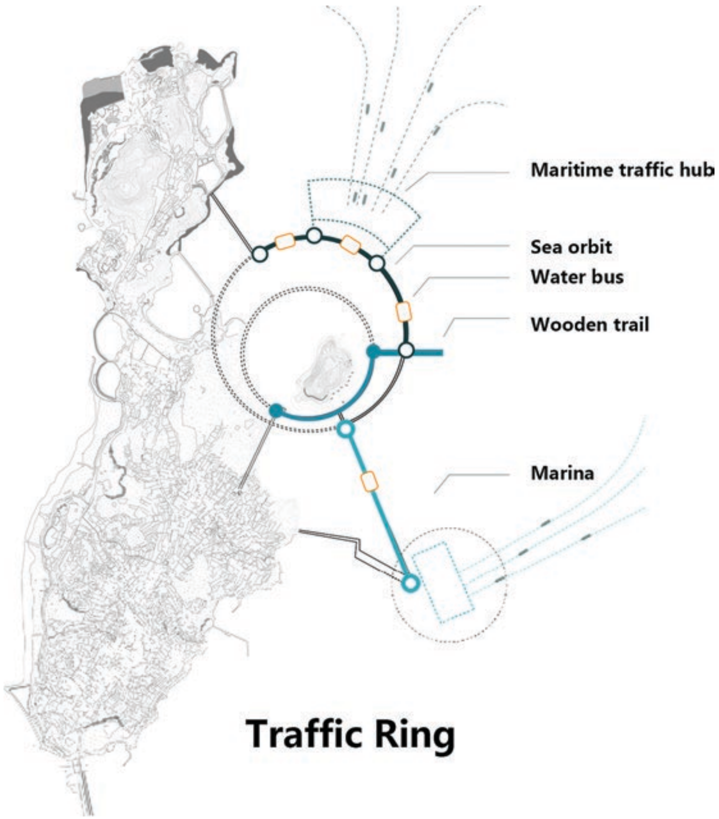

Fig. 10.16 Traffic ring system

Fig. 10.17 Sea orbit and waterbus in the traffic ring

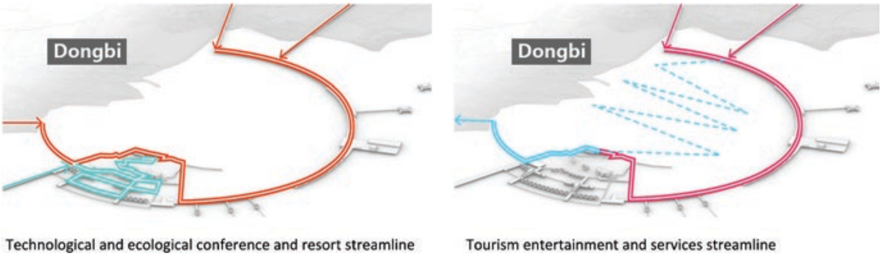

Fig. 10.18 Two streamline types

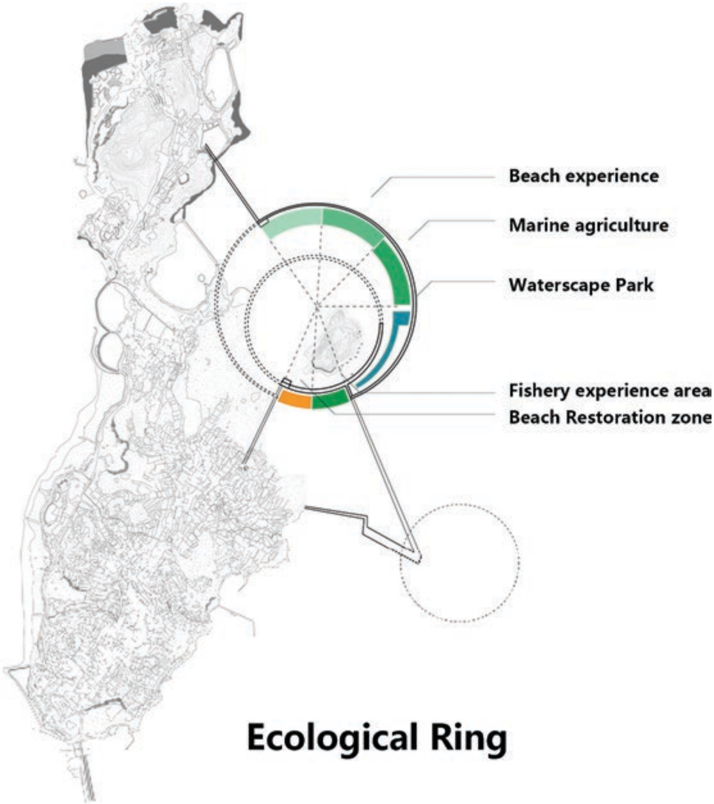

Fig. 10.19 Ecological ring system

System 2: Ecological Ring

An important function of the "O" ring is to provide a means for tourists to experience the island's natural environment (Fig. 10.19). When people pass through the "O" ring, they enter experience areas with different natural landscapes. The first is the beach experience area, where people can undergo an immersive experience when walking along the walkway. The second is the marine agriculture zone, where people can observe floating agriculture and view the industrial technological innovation of the island. The third is the waterscape park, formed by the ring's boundary. When the tide rises, the waterscape park is full of seawater. While with the tide ebbs, the water level falls, and the tide flat appears. However, the waterscape park will continue to store water, which makes it a public node and the entrance to the business zone. After the park, people come to the fishery experience area, where they can follow local residents to participate in harvest activity after the tide falls. The last part of the ring is the beach restoration zone, which is maintained and protected as an experimental natural restoration area. These five main landmarks will help people enjoy the scenery and enjoy a rich experience as they walk along the ring.

System 3: Functional Ring

Another important purpose of the "O" ring is to integrate more in-demand functions to complement the island's development (Fig. 10.20). Because of the island's limited construction area, new functions will be added on the "O" ring, integrated with

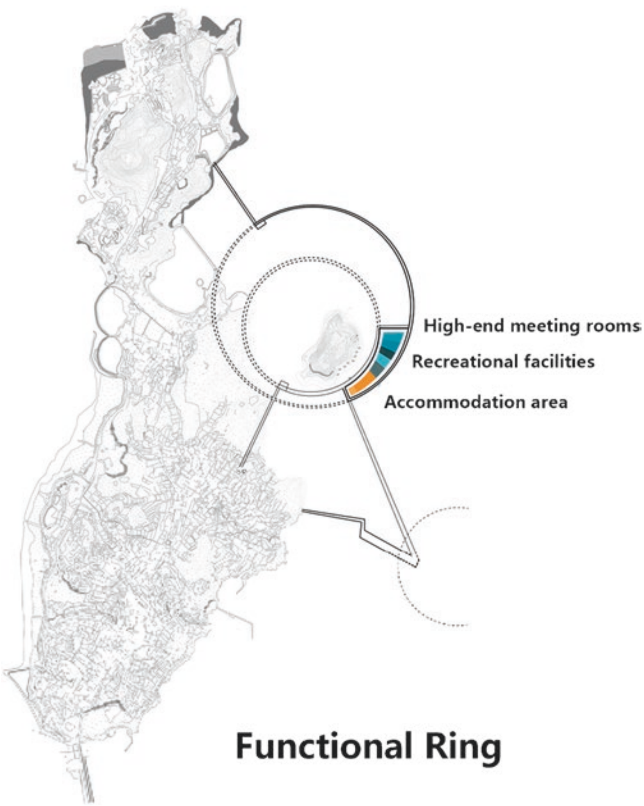

Fig. 10.20 Functional ring system

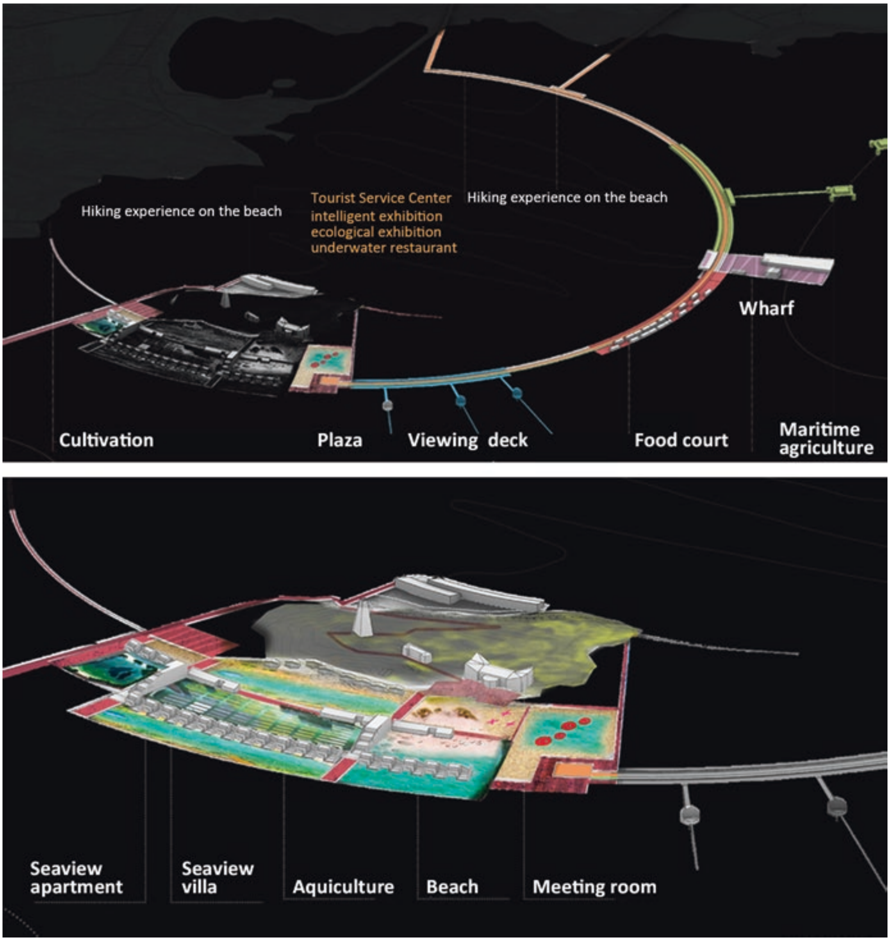

Fig. 10.21 Functions to Be Added in the future

the streamlines. To satisfy varying visitor needs, several meeting rooms, recreational facilities, and accommodations will be constructed on the eastern part of the island based on original service facilities. There are also several reserved sections and abundant space on the ring to develop and add new functions in the future (Fig. 10.21).

System 4: Monitor Ring

In the design, intelligent facilities (such as sensors) are added to the material ring to monitor and record the quality of and changes in the marine environment. Thus, the "O" ring also behaves as a sea-monitoring center (Fig. 10.22). For example, there

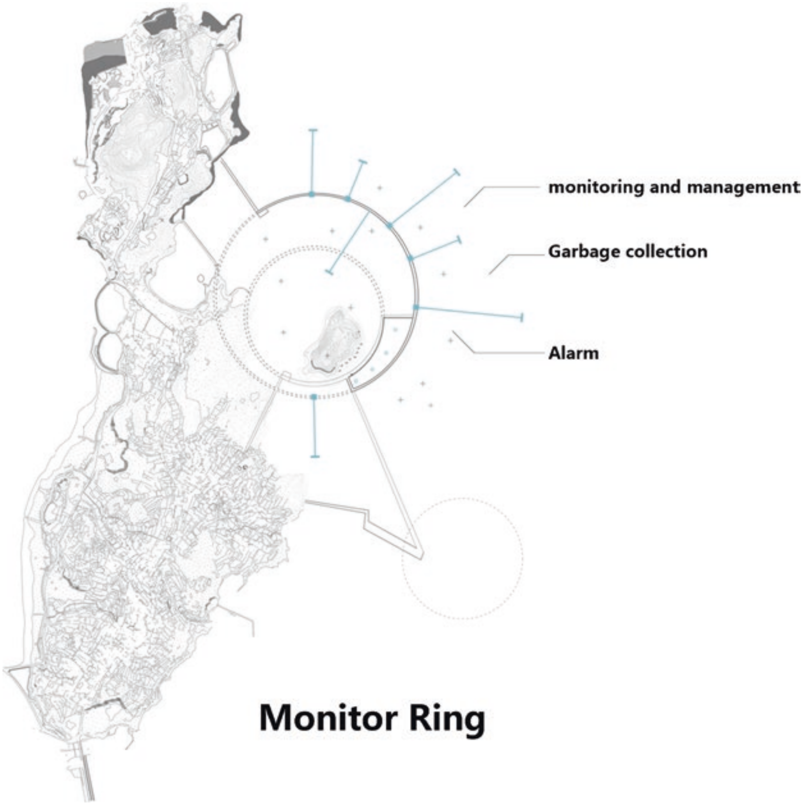

Fig. 10.22 Monitor ring system

are several extensions of various lengths reaching into the sea on which sensing devices are installed to detect floating objects (Fig. 10.23). When these sensors detect a floating object, the center is notified and marine robots dispatched to pick up the objects. If anyone is found in an emergency or danger, an alarm will be issued, and a rescue immediately carried out.

System 5: Information Ring

The last function of the "O" ring is to collect data generated by tourists and the environment, and thus, it is referred to as the "information ring" (Fig. 10.24). The core part of the ring is an information-processing center that controls various smart facilities. Certain smart facilities, such as smart lights, can be installed at fixed positions on the ring to collect information. For example, smart lights can automatically coordinate their brightness according to the human flow and the real-time electricity use. Smart trash bins can identify trash types, sort them automatically, and break them down intelligently. In addition, individuals can obtain real-time monitoring

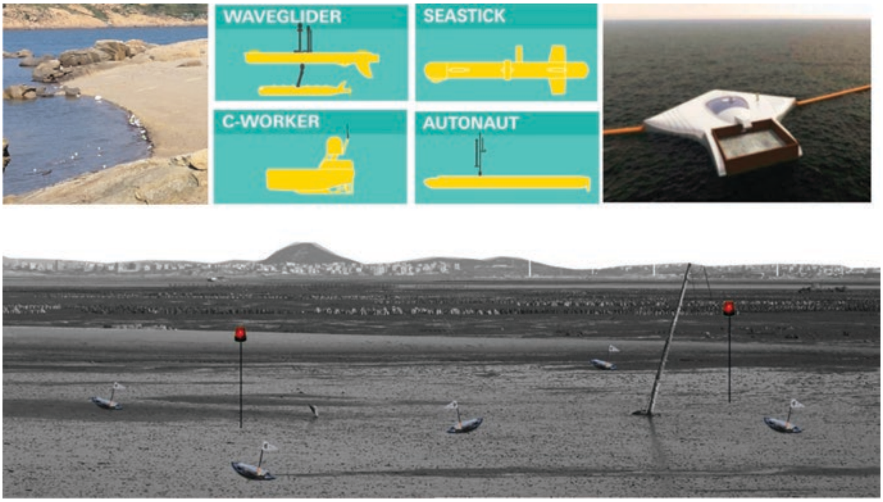

Fig. 10.23 Monitoring the condition of sea

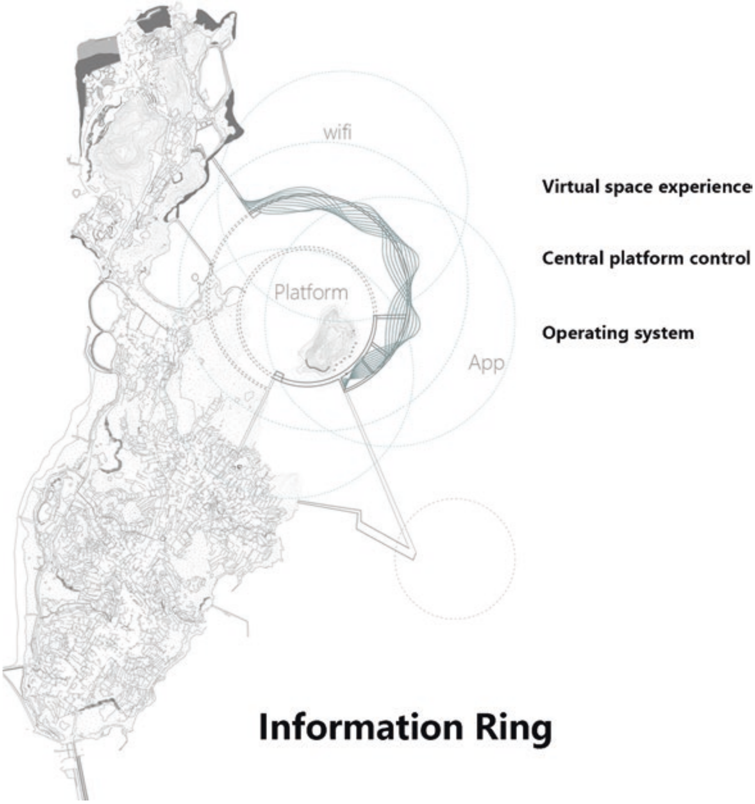

Fig. 10.24 Information ring system

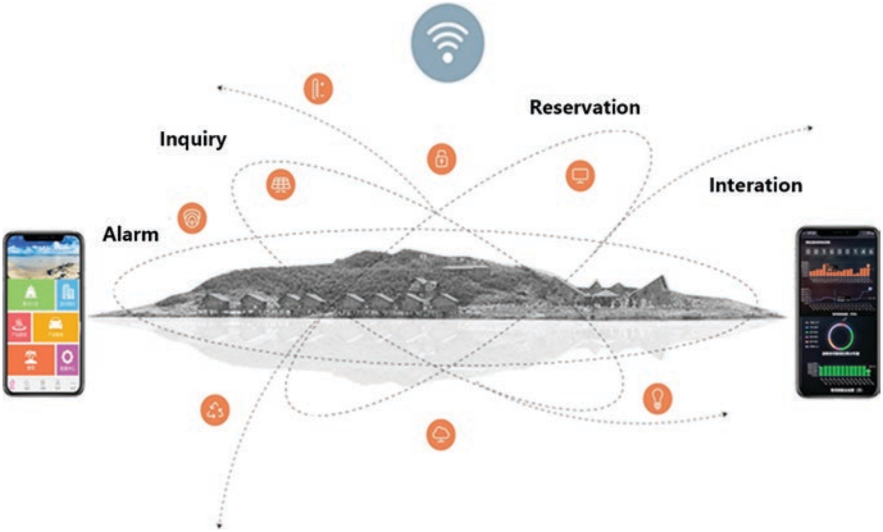

Fig. 10.25 Private operation system based on the information system

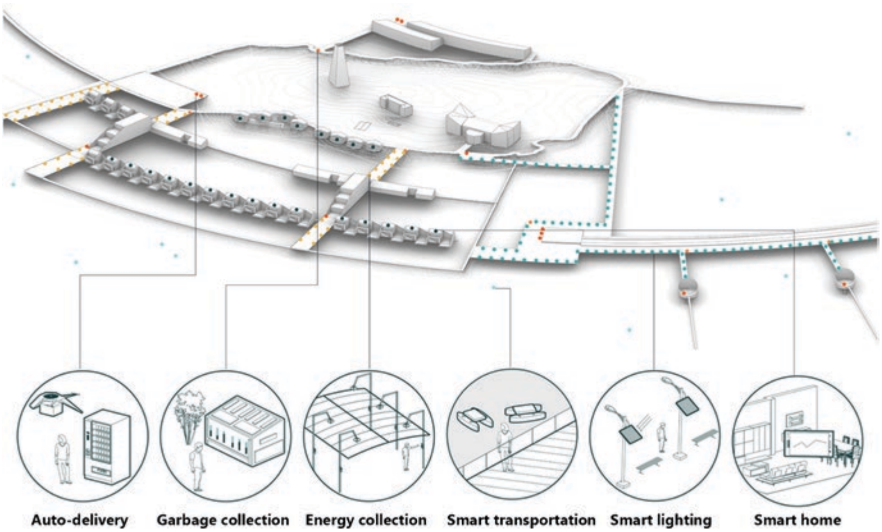

Fig. 10.26 Smart system for smart facilities

information through applications on their personal smartphones (Fig. 10.25). Moreover, information regarding bicycle or meeting room availability, show times, and festival events can be searched on the APP service. Accordingly, tourists can make reservations and arrange their itineraries in advance (Fig. 10.26).

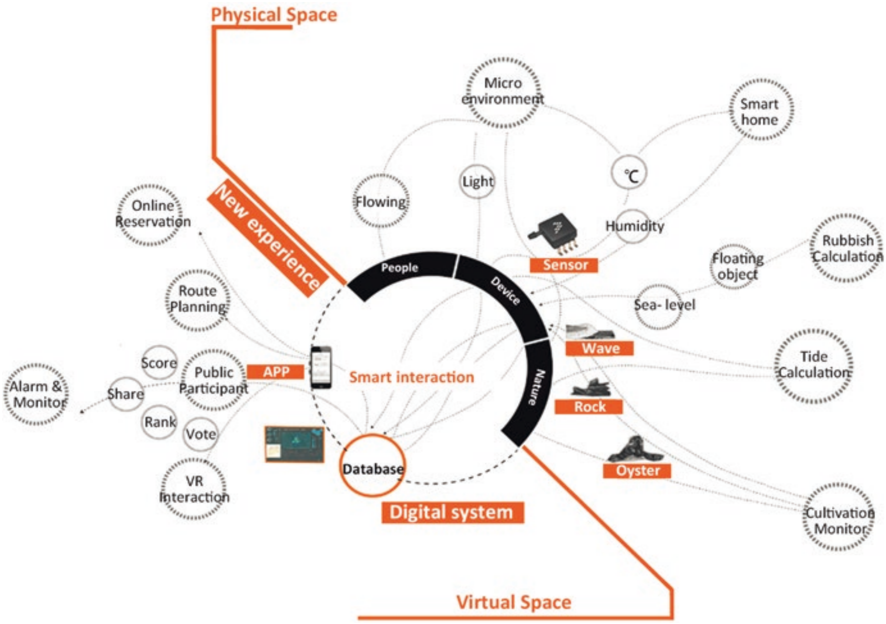

Fig. 10.27 Smart technologies applied to enhance the interaction between physical and virtual space

10.6 Augmenting Nature with Science and Technology

Traditionally, the interaction between nature and the built environment is primarily confined to visual experience, which always maintains distance, and thus full sensory stimulation is lacking. However, in the future, with the help of new technologies, there will be different ways to explore interaction between the natural and built environments (Fig. 10.27). In this design, a more interesting and friendly way is introduced to bring people close to nature through technology and online interaction. First, there is a digital system that supports smart interaction. The entire system consists of a two-part agent. One part is the physical participants, such as people, devices, and the physical environment. The other is the virtual online surroundings, such as a database and a mobile phone application. In this way, people can check and evaluate information regarding nature, such as the weather, the identity of plants, and the sea level, and they can also experience virtual scenery through VR technology.

We use two examples to illustrate the idea of employing technology to enhance the environment. For instance, in an ebb experience scenario, when the ebb falls, the tidal flat appears, and the smart runway and monitor starts to function, whereby the monitor forecasts the time of the tide rising and sends feedback to visitors through

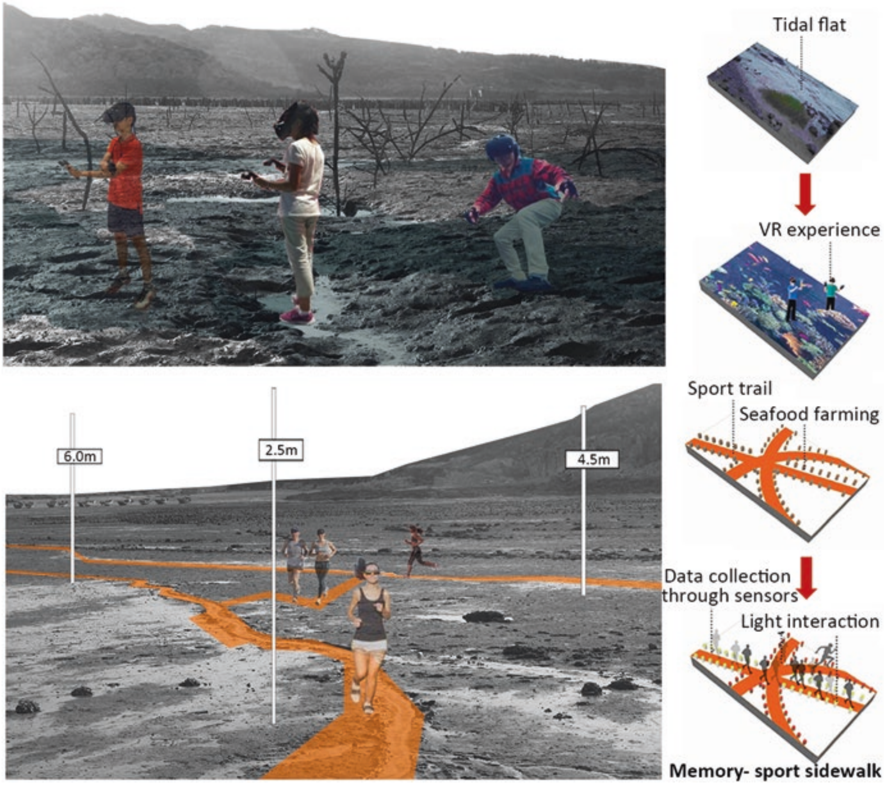

Fig. 10.28 New experience of nature with VR glasses

a phone message, helping them plan a route. At the same time, the monitor distributes air from the flat level to simulate the condition of streams, changing the height of the air supply outlet to simulate the elevation of the water surface. Thus, whenever someone arrives at a new spot, he or she can sense the water's height in the rising-tide condition. In this way, people can personally experience the pleasure provided by the environment. Additionally, people can wear VR glasses to experience a virtual underwater world, where they can play with marine animals and learn about their living conditions (Fig. 10.28).

The other example involves enhancing the experience of sea farming with technology. The oyster industry is a feature of local farming. When the tide falls, the oysters are exposed. Viewed from the shore, the oyster-farming scene is spectacular. In this design, we use lighting design to emphasize the scene. For each cluster of oysters, lighting and a sensor will be installed to monitor the degree of its grade of maturity. The lighting color will change according to the period of the oyster's life cycle. During the night, there will be a light show on the tide, and it will be fun to distinguish different colors and various clusters of oysters. Such light scenery will

Fig. 10.29 New experience of light scenery simulating oyster clusters

also change as time passes. This special scene is also an icon of the island and reflects the concept of combining technology and nature (Fig. 10.29).

10.7 Conclusion and Discussion

This research-based design combines the DAD method with future-oriented thinking about the island. Three aspects are considered in the design: data-based design, virtual-based reality, and natural-based technology. Specifically, we use quantitative analysis to objectively evaluate the current conditions and problems of the design site. This approach provides a basis for the generation of design strategies and helps achieve a scientific and rational design. In the design process, we integrate digital innovation and a traditional spatial intervention strategy. We fully embrace new technologies and apply them in various scenarios. New facilities and technologies are used to create new activities and to enhance the experience of the real world. As a result, a combination of “online and offline” and “virtual experience and real activities” is realized. Because Huangguan Island is known for its natural environment, we adopt strategies to protect that environment and enhance the “sense of nature” by using technology (Fig. 10.30). These three aspects represent the core of the design, which also reflects the main concept of the third type of DAD.

However, certain limitations to the design remain. First, the research was limited by the restricted data. Thus, the circumstances of the island are not fully described, which may cause bias in the judgments applied in the design. In addition, the study

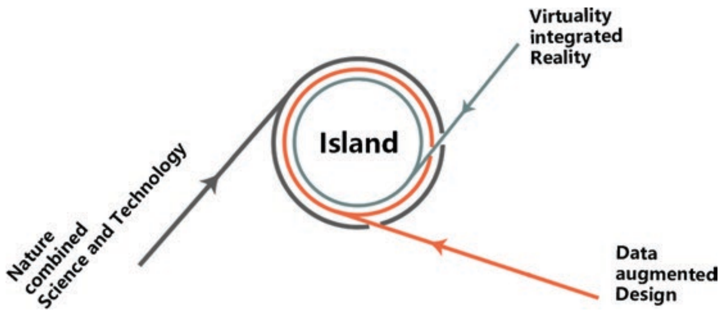

Fig. 10.30 Three main aspects considered in this design

uses only two examples to describe the application of the design concept in detailed scenarios. More scenarios involving more technologies must be investigated. Finally, the relationship between nature, the built environment, and the digital system should be discussed in greater detail.

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Appendix 1: Data in New Data Environment

Y. Long, E. Zhang, *Data Augmented Design*, Strategies for Sustainability,
https://doi.org/10.1007/978-3-030-49618-0

Data Reflects Physical Environment

Characteristics	Data	Data sources	Dimensions				
			Boundary	Land use	Form	Quality of space	Environment
Data reflects physical environment	Remote sensing imagery	Google Earth, NASA Reverb, USGS Earth Explorer, JAXA's Global ALOS 3D World et al.	Mathieu et al. (2007), Baker and Smith (2019), Chai and Seto (2019)	Meng (2015), Alo and Pontius (2008)	Wentz et al. (2018)	Haase et al. (2019), Nichol et al. (2006)	–
	Street view images (SVIs)	Google Map, Baidu Map, Gaode Map et al.	–	–	Harvey et al. (2015), Li et al. (2019)	Rundle et al. (2011), Bader et al. (2015), Long et al. (2015), Shen et al. (2018), Tang and Long (2019)	–
	POI (point of interest)	Google Map, Baidu Map, Gaode Map, OpenStreetMap et al.	Long et al. (2018)	Song et al. (2018), Liu and Long (2016), Lorenzo et al. (2012)	Li et al. (2018a, b)	Seresinhe et al. (2018)	–
	Road network	OpenStreetMap	Liu and Long (2016), Jin et al. (2017)	–	Long and Huang (2019), Boeing (2018)	–	–
	Building's footprint	OpenStreetMap	–	Seresinhe et al. (2018)	Berghauser Pont et al. (2019), Berghauser Pont and Haupt (2010), Steadman (2014), Perez et al. (2018)		

Characteristics	Data	Data sources	Dimensions				
			Boundary	Land use	Form	Quality of space	Environment
	Air quality (air pollution index (API) and air quality index (AQI))	Environmental sensors, environmental protection monitoring center	–	–	–	–	Verdonck et al. (2018), Tian et al. (2019)

Data Reflects Citizens' Activities

Characteristics	Data	Data sources	Dimensions			
			Traffic and tracks	Activities and behaviors	Vitality (aggregation of activities)	Sentiment
Data reflects citizens' activities	Nighttime light images	NOAA, NOAA's Comprehensive Large Array-data Stewardship System (CLASS), NASA earthdata, LAADS DAAC	–	–	Li et al. 2019, Jin et al. (2017)	–
	Mobile phone signaling data	Global system for mobile communication	Liu and Long (2016), Lorenzo et al. (2012), Noyman et al. (2019)	Xiao et al. (2019), Ratti et al. (2006), Lorenzo et al. (2012), Noyman et al. (2019)	Ratti et al. (2006), Reades et al. (2009), Noyman et al. (2019)	–

Characteristics	Data	Data sources	Dimensions			
			Traffic and tracks	Activities and behaviors	Vitality (aggregation of activities)	Sentiment
	Location-based service data (social network system, SNS)	Twitter, Facebook, Weibo, WeChat, Flickr	Huang et al. (2019)	Long et al. (2015), Huang et al. (2019)	Long and Huang (2019), Chen et al. (2018), Jin et al. (2017)	Seresinhe et al. (2018), Huang et al. (2019), Mogaji and Erkan (2019)
	Location-based service data (sports tracking application)	Sports Tracker, Strava	Korpilo et al. (2017)	Lee and Kwan (2018), Arif et al. (2014)	Hasanzadeh (2019)	–
	Location-based service data (e-commerce consumption data)	Amazon, DianPing, MeiTuan, TaoBao, JingDong	–	Reades et al. (2009)	Long and Huang (2019)	–
	Internet search queries	Google, Baidu	–	Jin et al. (2017)	–	Chauvet et al. (2016)
	GPS based transport data	Sharing bikes (Mobike, DiDi, Meituan), Sharing taxies (DiDi, Uber)	Taczanowska et al. (2014), Liu and Long (2016), Bielański et al. (2018)	–	Bielański et al. (2018)	–
	Smart card data (SCD)	Public transport company	Long and Thill (2015)	Zhang et al. (2018), Long et al. (2015)	–	–
	Fixed citizen sensors	Wi-Fi, LADAR, infrared sensor	Henderson et al. (2008), Meneses and Moreira (2012)	Poucin et al. (2018), Afanasyev et al. (2010)	Naini et al. (2011); Meneses and Moreira (2012)	–

Characteristics	Data	Data sources	Dimensions			
			Traffic and tracks	Activities and behaviors	Vitality (aggregation of activities)	Sentiment
	Wearable devices	Eye-tracking devices, health-monitoring sensors, smartwatch, fitness tracker, sports tech, running watches, VR	Wolf and Wohlfart (2014); Depeau et al. (2017)	Matisziw et al. (2016), Depeau et al. (2017)	Depeau et al. (2017)	Borgers et al. (2010), Franěk et al. (2019), Liu et al. (2019)

Appendix 2: Centers and Labs (in Chronological Order)

Y. Long, E. Zhang, *Data Augmented Design*, Strategies for Sustainability,
https://doi.org/10.1007/978-3-030-49618-0

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
1	Santa Fe Institute	1984	Santa Fe Institute (SFI) (https://www.santafe.edu)	Our researchers endeavor to understand and unify the underlying, shared patterns in complex physical, biological, social, cultural, technological, and even possible astrobiological worlds. Our global research network of scholars spans borders, departments, and disciplines, unifying curious minds steeped in rigorous logical, mathematical, and computational reasoning. As we reveal the unseen mechanisms and processes that shape these evolving worlds, we seek to use this understanding to promote the well-being of humankind and of life on earth.	• Complex intelligence: natural, artificial, and collective • Complex time—adaptation, aging, arrow of time • Invention and innovation • Limits • Mental models of complexity The Feldstein program on law, history, and regulation	*Social networks, big data, and physics-powered inference*: use physics-inspired methods to find structure within large data sets and determine when these structures are statistically significant *Cities, scaling, and sustainability*: develop theoretical insights about cities that can inform quantitative analyses of their long-term sustainability in terms of the interplay between innovation, resource appropriation, and consumption and the makeup of their social and economic activity.	Santa Fe, New Mexico, United States

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
2	The School of Architecture and Planning, Massachusetts Institute of Technology (MIT)	1985	The MIT Media Lab (https://www.media.mit.edu/)	MIT Senseable City Lab is an interdisciplinary research lab working to invent the future of everything. It research examines the deeper implications of where technology creation and adoption has led us—and where we want to go next	• City science • Human dynamics • Space enabled • Responsive environment • Civic media	*Reversed urbanism project*: explore a novel method to analyze diverse behavioral patterns in large urban populations and to associate them with discrete urban features by utilizing machine learning and anonymized telecom data to understand which fragments of the city has greater potential to attract dense and diverse populations over longer periods of time	Cambridge, Massachusetts, United States

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
3	The Bartlett Faculty of the Built Environment, University College London	1995	The Bartlett Centre for Advanced Spatial Analysis (CASA) (https://www.ucl.ac.uk/bartlett/casa/)	The center is established to lead the development of a science of cities drawing upon methods and ideas in modeling, sensing the urban environment, visualization, and computation It seeks to examine and offer solutions to the problems of resource efficiency and effective planning and governance shared by all cities. Our vision is to play a central role in the science of smart cities applying it to city planning, policy, and architecture in the pursuit of making our cities better places to live	• Application of computer models • Data visualization techniques • Innovative sensing technologies • Mobile applications and urban theory linked to city systems	*Applicable urban informatics*: assemble, study, and interpret a variety of case studies in large cities where new digital technologies are being developed and implemented *Urban dynamics lab*: explore and address questions at the intersection of city and regional development and spatial analytics, data science and computing	London, United Kingdom

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
4	The School of Architecture and Planning, Massachusetts Institute of Technology (MIT)	2003	MIT Civic Data Design Lab (http://civicdatadesignlab.mit.edu/)	The civic data design lab works with data to understand it for public good. We seek to develop alternative practices which can make the work we do with data and images richer, smarter, more relevant, and more responsive to the needs and interests of citizens traditionally on the margins of policy development. In this practice we experiment with and develop data visualization and collection tools that allow us to highlight urban phenomena. Our methods borrow from the traditions of science and design by using spatial analytics to expose patterns and communicating those results, through design, to new audiences	• Mobility • Ghost cities • Data visualization of urban data	*Data action project*: develop and prototypes examples of how data visualization can be used to influence debate on civic issues and ultimately affect policy	Cambridge, Massachusetts, United States

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
5	The School of Architecture and Planning, Massachusetts Institute of Technology (MIT)	2004	MIT Senseable City Lab (SCL) (http://senseable.mit.edu/)	The mission of the Senseable City Laboratory is to anticipate these changes and study them from a critical point of view. Not bound by the methodologies of a single field, the Lab is characterized by an omni-disciplinary approach: it speaks the language of designers, planners, engineers, physicists, biologists, and social scientists	• Urban sensing • Sharable cities • Mobility and vehicles	*Friendly cities project*: use a call detail record (CDR) data set collected in Singapore to identify places in the city that bring together friends versus those that facilitate chance encounters among strangers *Cityways project*: explore the cities of San Francisco and Boston using billions of data points collected via activity monitoring apps	Cambridge, Massachusetts, United States

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
6	Carlo Ratti	2004	Carlo Ratti Associati (CRA) (https://carloratti.com/)	Carlo Ratti Associati is an international design and innovation office based in Torino, Italy, with branches in the United States and the UK. Drawing on Carlo Ratti's research at the Massachusetts Institute of Technology Senseable City Lab, the office is currently involved in many projects across the globe, embracing every scale of intervention—from furniture to urban planning. The work of the practice merges design with cutting-edge digital technologies, so as to contribute to the creation of an architecture "that senses and responds"	• Application of digital technologies in architecture, planning, and design	*ANAS smart road*: involve a pioneering infrastructure system featuring drones that are able to deliver first-aid support, as well as sensing poles that can send useful information to both today's drivers and tomorrow's self-driving vehicles. The program experiments with new ways of gathering and sharing data about mobility, with the objective of improving safety conditions and traffic management	Torino, Italy, with branches in the United States and the UK

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
7	The Graduate School of Architecture, Planning and Preservation, Columbia University	2004	Spatial Information Design Lab (http://c4sr.columbia.edu/projects/)	The Center for Spatial Research sponsors research and curricular activities built around new technologies of mapping, data visualization, data collection, and data analysis. CSR focuses on data literacy as well as interrogating the world of "big data," working to open up new areas of research and inquiry with advanced design tools to help scholars, students as well as our collaborators and audiences, to understand cities worldwide—past, present, and future	• Architecture and justice • Social media and the psychological city • Transportation and mobility • Ecology	*CitiBike rebalancing study*: investigate into ways to rebalance CitiBike stations throughout New York City via creating a series of visualizations which should serve as a starting point for further analysis *Conflict urbanism: Colombia project*: analyze and visualize the documented aspects of the conflict in Colombia in order to put forward policy recommendations for the transitional justice and peacebuilding process	New York City, United States

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
8	The Faculty of the Built Environment, University of New South Wales	2005	City Futures Research Centre (https://cityfutures.be.unsw.edu.au/)	Our work spans the interrelated areas of urban planning, housing, health and well-being, design, urban development, and social policy. In undertaking this research, we collaborate with a range of academic researchers, both within UNSW and at universities across Australia, Asia, and Europe. Our applied focus also involves strong partnerships with local, state, and federal government agencies as well as industry stakeholders and community groups	• Equity • Governance • Productivity • Renewal	*An integrated information model to support metropolitan planning*: integrate diverse types of urban data using an open-standard geospatial information model to research the outcomes of major urban renewal proposals in collaboration with both a state and local government planning instrumentalities	Sydney, Australia

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
9	QUT Design Lab, the Queensland University of Technology	2006	QUT Urban Informatics (https://research.qut.edu.au/designlab/groups/urban-informatics/)	The Urban Informatics group in the QUT design lab examines, communicates, and designs responses to how people, place, and technology come together to create urban experiences. It is a world-leading design-led research across people, place, and technology beyond smart cities	• Augmented urban spaces • Urban narratives • Environmental sustainability	*Augmented and top-projected visualisation of real-time data on a city-scale model*: study novel approaches to urban data visualization by augmenting QUT's existing physical architectural scale model of Brisbane with live data feeds which are overlayed through augmented reality and top-projection visualization approaches	Queensland, Australia

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
10	The University of Tokyo	2006	Center for Spatial Information Science (CSIS) (http://www.csis.u-tokyo.ac.jp/english/index.html)	The goal of the center is to be a joint usage/research center available to researchers around the country for work related to Spatial Information Science and to create and provide a spatial database for research purposes. Spatial information science is a field that develops systematic methods for constructing, managing, analyzing, integrating, and communicating spatial data (i.e., natural, social, economic, and cultural data with location information) and that studies their applications to other fields. Moreover, spatial information science aims to construct "spatial knowledge," which refers to the knowledge of nature, society, economy, and culture relating to spatial data	• Spatial information analysis • Spatial information engineering • Spatial socioeconomic research • Joint Usage and Research (JUR) • Space system and geospatial information engineering (CSIS-S4D) (corporate sponsored research programs)	Wildlife monitoring in contaminated environments through human–computer–biosphere interaction; dynamic transportation modeling with mobile sensing technologies	Tokyo, Japan

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
11	ETH Zurich and Singapore's National Research Foundation (NRF)	2010	Future Cities Laboratory (FCL) (https://fcl.ethz.ch)	Sustainable future cities: through science, by design, in place. Science provides the basis for understanding how cities develop and interact with the environment at different scales. Design is a collaborative process that combines analytical techniques, imaginative strategies, and transdisciplinary knowledge to generate new ideas and bring them to fruition. Places result from common processes (growth and decline; competition and co-operation; ebb and flow of capital, people, goods, and ideas; and climate change) and differentiating factors (geography, culture, language, and history)	• High-density mixed-use cities • Responsive cities • Archipelago cities • Research to application • Collaboration platforms	*Mobility and transportation planning*: Investigate the flows of people and goods at different time scales to manage, plan, and optimize these flows in the context of medium- and long-term policy making and urban planning	Singapore

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
12	University of Oxford	2011	The Oxford Internet Institute (OII) (https://www.oii.ox.ac.uk/)	The Oxford Internet Institute is a multidisciplinary research and teaching department of the University of Oxford, dedicated to the social science of the Internet. Digital connections are now embedded in almost every aspect of our daily lives, and research on individual and collective behavior online is crucial to understanding our social, economic, and political world	• Digital economies • Digital knowledge and culture • Digital politics and government • Education, digital life, and well-being • Ethics and philosophy of information • Information geography and inequality • Information governance and security	*Social data science*: generate theory-informed predictive models and underpin the way we understand and solve social problems, emphasizing on empirical observation of patterns in large-scale data, quantitative modeling, and experiments *Education, digital life, and wellbeing*: employ theoretically diverse approaches and an array of methods (including experiments, interviews, and national surveys) to investigate the benefits and risks associated with the Internet in everyday life	Program

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
13	Northeastern University and Harvard University	2011	Boston Area Research Initiative (BARI) (https://www.northeastern.edu/csshresearch/bostonarearesearchinitiative/)	BARI focuses on three major areas of activity: pursuing core research-policy partnerships and projects that use modern data to probe major themes and challenges facing greater Boston; developing technologies that make emergent data sources accessible for research, policy, and practice; convening and supporting cutting-edge research-policy work in the region	• Neighborhoods • Urban commons • Equity in public schools • Smart cities	*"Seeing" Neighborhoods through "Big" Data*: generate an extended library of ecometrics, including measures of: "broken windows," or physical disorder, and civic engagement from 311 reports; social disorder and crime and medical emergencies from 911 calls; and growth and investment from building permits	Boston, Massachusetts, United States

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
14	New York University and NYU-Poly, along with a consortium of world-class universities and some of the foremost international tech companies	2012	Center for Urban Science and Progress (CUSP) (http://cusp.nyu.edu/)	New York University's Center for Urban Science and Progress (CUSP) is an interdisciplinary research center dedicated to the application of science, technology, engineering, and mathematics in the service of urban communities across the globe. Using New York City as our laboratory and classroom, we strive to develop novel data- and technology-driven solutions for complex urban problems	• Urban Complexity Lab • Urban Modeling Group • CUSP Urban Observatory (CUSP-UO) • Dynamical Systems Laboratory (DSL) • Building Informatics and Visualization Lab (biLAB) • Behavioral Urban Informatics, Logistics, and Transport Laboratory (BUILT)	*Urban informatics*: collect, store, and process data to better understand and improve urban system and the quality of life	New York City, United States

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
15	Mansueto Institute for Urban Innovation of the University of Chicago and Argonne National Laboratory	2012	Urban Center for Computation and Data (UrbanCCD) (https://www.urbanccd.org/#urbanccd)	The center creates computational research tools and leads initiatives that unite academic researchers, government agencies, architectural firms, private enterprise, and civic volunteers in ambitious efforts to understand and improve our cities	• Modular sensor boxes • Computational modeling tool • Data analysis	*Array of Things (AoT)*: a network of interactive, modular sensor boxes that collect real-time data on a city's environment, infrastructure, and activity for research and public use *Plenario*: the cyberinfrastructure, technologies, and tools used to make the rich set of urban open data available were designed primarily to support the analysis of individual data sets rather than exploring relationships among many data sets	Hyde Park, Chicago, United States

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
16	University College London, Imperial College London and Intel	2012	The Intel Collaborative Research Institute for Sustainable Connected Cities (ICRI Cities) (http://2012.cities.io/)	The Intel Collaborative Research Institute is concerned with how to enhance the social, economic, and environmental well-being of cities by advancing compute, communication, and social constructs to deliver innovations in system architecture, algorithms, and societal participation	• Harnessing the invision city • Enabling connected communities • Sustaining sustainable practices • City as a platform	*Assistive technologies for data-gathering communities:* assess some key aspects of communal data-gathering practice in community groups like OpenStreetMap, Cosm, Air Quality Egg, the Smart Citizen Kit, Sensorpedia, and others	London,United Kingdom
17	University of Warwick	2012	Centre for Interdisciplinary Methodologies (CIM) (https://warwick.ac.uk/fac/cross_fac/cim/about/)	CIM is dedicated to expanding the role of interdisciplinary methods through new lines of inquiry that cut across disciplinary boundaries, both intellectually and institutionally	• Applications, interfaces, gestures • Experiments in participation • Methods and methodologies • Changes and continuity	*Issue mapping online*: introduces a set of digital techniques for the detection, analysis, and visualization of topical affairs to provide practical instructions and examples to guide social and cultural researchers in the use of these techniques	Coventry, United Kingdom

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
18	Dr. Ying Long and his collaborators	2013	Beijing City Lab (BCL) (https://www.beijingcitylab.com)	The Beijing City Lab (BCL) is a research community dedicated to (but not limited to) studying China's capital Beijing. The Lab focuses on employing interdisciplinary methods to quantify urban dynamics, generating new insights for urban planning and governance, and ultimately producing the science of cities required for sustainable urban development	• Data augmented design • Planning support systems • Shrinking cities • Urban form • Healthy cities • The science of new cities	*Redefining Chinese city system*: proposed a method for Functional Urban Areas (FUA) identification that relies on ride hailing big data. In this study, over 43 million anonymized 2016 car-hailing records were collected from Didi Chuxing, the largest car-hailing online platform in the world (to the best of our knowledge). A core–periphery approach is then proposed that uses nationwide and fine-grained trips to understand functional urban areas in Mainland China	Beijing, China

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
19	Beijing Tsinghua Tongheng planning and Design Institute	2013	Tsinghua Urban Planning and Design of Digital City Institute (http://dcrc.thupdi.com)	Digital City Institute is a professional research institution dedicated to digital city, 3D geographic information and related technologies	• Smart city system • Smart infrastructure • Digital media and display	*Digital Macao 3D city information system*: a network information platform, which combines the Urban Cadastral and government information through 3D GIS technology, to realize the special use, affairs sharing, and open data of governance	Beijing, China
20	Carnegie Mellon University	2014	Metro21: Smart Cities Initiative (CMU's Metro21) (https://www.cmu.edu/metro21/)	Smart Cities Institute seeks to research, develop, and deploy the twenty-first century solutions to the challenges facing metro areas	• Infrastructure • Citizen engagement • City operations • Climate change and environment • Transportation and mobility • Water and sewer	*Heinz platform Pittsburgh*: visually measure air quality in Pittsburgh by using digital images *City-wide building data analytics*: support data-driven policy making, building portfolio energy and indoor environmental quality (IEQ) optimization, and building occupants' engagement in energy conservation	Pittsburgh, Pennsylvania, United States

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
21	The UKRI-ESRC and the University of Glasgow	2014	Urban Big Data Centre (UBDC) (http://ubdc.ac.uk/)	UBDC is a research centre and national data service based at the University of Glasgow. We promote the use of big data and innovative research methods to improve social, economic, and environmental well-being in cities	• Education and skills • Housing and neighborhoods • Transport and infrastructure • Urban governance	*Future transport services*: explore future forms of transport services and infrastructure which are likely to be transformed by automation and sharing platforms in the near future	Glasgow, United Kingdom
22	Wageningen University and Research (WUR) and Delft University of Technology (TU Delft), and Massachusetts Institute of Technology (MIT)	2014	Amsterdam Institute for Advanced Metropolitan Solutions (AMS Institute) (http://www.ams-institute.org/)	Our mission is to develop a deep understanding of the city—sense the city—to design solutions for its challenges, and integrate these into the city of Amsterdam. Our research portfolio revolves around applied technology in themes such as water, energy, waste, food, data, and mobility, and integrating these themes to create an innovative, sustainable, and just city	• Smart urban mobility • Urban energy • Climate resilient cities • Metro food systems • Responsible urban digitization • Circularity in urban regions	*Data demonstrators*: analyze and visualize relevant data to promote practical solutions to the challenges of daily life in the city	Amsterdam, Netherlands

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
23	Beijing Tsinghua Tongheng planning and Design Institute	2014	Innovation Center for Technology (http://ict.thupdi.com/about/?tag=intro)	The Innovation Center for Technology uses big data analysis to assist in urban development, planning, and management, focusing on the research and development of model tools and information platforms in population, industry, space, transportation, housing, new area. It aims to solve problems through six main steps—problem diagnosis, cross analysis, scheme experiment, scientific decision-making, monitoring and early warning, implementation and evaluation. Knowledge integration, data integration, and technology integration are three core concepts of this center	• Smart city production • Urban future research • Intelligent computing • Data management • Smart city research	*Urban cognitive system based on social behavior data and its demonstration application*: choose multisource social and behavior data and organize a system to support the refined governance and decision-making. The whole process contains four steps—processing portrait, modeling analysis, system research and development, and demonstration application	Beijing, China

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
24	Baidu Map Eye and China Academy of Urban Planning and Design	2017	Joint Innovation Laboratory (http://www.china-up.com)	Joint Innovation Laboratory integrates advantages of Baidu Map Eye and China Academy of Urban Planning and Design, researches on key fields of urban planning, to build a national intelligent bank for urban planning and construction in China	• Dynamic monitoring and policy support of urbanization • Urban space diagnosis, evaluation, and simulation • Artificial intelligence and smart management • Decision-making support for urban space • Business consulting	*Image recognition of Beijing urban street landscape based on deep learning*: use deep neural networks to semantically segment a total of 278,624 street scene images collected from various streets in Beijing. Various types of landscapes such as trees, sky, pavement, and buildings on most streets in the city are identified to describe different "personality" of different streets and their spatial distribution characteristics	Beijing, China
25	China Academy of Urban Planning and Design and Ali Baba	2018	Future City Laboratory (http://www.china-up.com)	The Future City Laboratory integrates all advantageous resources, jointly develops intelligent comprehensive solutions for future cities, and devotes itself to inject new power into Chinese cities and provides new samples for urban innovation in the world	• Future urban planning management and control • Future urban management operation framework • Exploration of Xiong'an New District	*Xiong'an New District digital planning platform*: with the help of digital planning platform, Xiong'an is exploring a new way of urban planning and design. It builds a virtual city based on the real city with full space–time perception, all things linked and whole cycle iteration	Beijing, China

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
26	Department of Environmental Science, Aarhus University	2018	Big Data Centre for Environment and Health (BERTHA) (https://projects.au.dk/bertha/)	The mission of BERTHA is to assemble, link, and analyze Big Data from diverse data sources to make substantive progress in the understanding of spatial life course environmental influences on cancer, cardio-respiratory diseases, diabetes, neurological diseases, allergy, mental health and well-being; to develop and extend algorithms and tools to spatially mine the data sources needed; to raise the capacity among health and environmental researchers to understand and benefit from the Big Data revolution by establishment of a comprehensive training program for PhD students, Post Docs, and senior scientists; to establish strong national and international research collaborations and partnerships focused on the interaction between spatial life course environmental and social influences and human health	• Environmental influences on health	N/A	Aarhus, Denmark

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
27	Department of Land Economy, the University of Cambridge	2019	Lab of Interdisciplinary Spatial Analysis (LISA) (https://www.landecon.cam.ac.uk/research/research-centres/lisa)	LISA is a Geographic Information Lab that allows congregating data, software, and expertise for spatial analysis in Land Economy's related subjects (planning, real estate and finance, environmental policy, environmental and climate change). LISA also acts a geographic information platform, providing the GIS and spatial analysis expertise though the provision of GIS and spatial analysis courses	• Complexity analysis and dynamic simulation • Creative cities/firms/industries simulation models • Energy efficient cities, urban form, and decision-making • Land use change and scenarios for city and regional planning • Spatial analysis and urban spatial metrics (in particular, metrics for urban growth and shrinkage) • Integrated land use and transport models • Big data, data mining, data validation, and model calibration	*Land use change and scenarios for city and regional planning*: SLEUTH model—CA model of urban and land use change. SLEUTH is a tightly coupled, modified cellular automaton model of urban and other land class change. Its main component is the Clarke Urban Growth Model (UGM) which drives a second component, the Deltatron land cover model	Cambridge, United Kingdom

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
28	Ash Center for Democratic Governance and Innovation at Harvard Kennedy School, Harvard	N/A	Data-Smart City Solutions (http://datasmart.ash.harvard.edu/)	Data-Smart City Solutions is working to catalyze adoption of data projects on the local government level by serving as a central resource for cities interested in this emerging field. We highlight best practices, top innovators, and promising case studies while also connecting leading industry, academic, and government officials. Our research focus is the intersection of government and data, ranging from open data and predictive analytics to civic engagement technology. We seek to promote the combination of integrated, cross-agency data with community data to better discover and preemptively address civic problems	• Civic data • Civic engagement • Health and human services • Mobility • Public safety	*A New City O/S*: proposes an entirely new governance model for forward-thinking cities to unleash innovation in a way that embraces today's technologies while restructuring government practices that are barriers to progress	Cambridge, Massachusetts, United States

Order	Host institute	Year established	Center	Brief introduction	Project themes	Representative projects	Location
29	The Faculty of the Built Environment, University of New South Wales	N/A	Smart Cities Research Cluster (SCRC) (https://www.be.unsw.edu.au/research/research-clusters/smart-cities)	The Smart Cities Research Cluster (SCRC) seeks to promote and advance the efficient design, planning, and delivery of urban environments and services through the use of information and communication technology with a focus on spatial technologies	• Develop participatory urbanism to empower citizens to interact in new, more efficient, and more meaningful ways • Develop resilient cities through the smart design of sustainable and flexible hi-tech infrastructure and service delivery • Promote and design cities as healthy, safe, and productive environments through the use of smart technologies and evidence-based design	*Modelling city futures–a scenario planning approach*: explore an envelope of future land use scenarios for Perth to Peel metropolitan region using the OWI PSS	Sydney, Australia

Appendix 3: Courses and Programs Related to Data Analytics and Spatial Informatics in Urban and Planning Fields (in Alphabetical Order by School Name)

Y. Long, E. Zhang, *Data Augmented Design*, Strategies for Sustainability,
https://doi.org/10.1007/978-3-030-49618-0

Order	School/Institute	Department/center/lab	Courses	Introduction	Website
1	ETH Zurich	Environment, Infrastructure and Architecture	Responsive Cities (edx)	Responsive cities define the future of urbanization. They evolve from smart cities, with a fundamental difference: The citizens move from the center of attention to the center of action. Responsive citizens use smart technology to contribute to planning, design, and management of their cities	https://sce.ethz.ch/en/programmes-and-courses/angebot-nach-cluster/environment-infrastructure-architecture.html?polycourseId=1526
2			Smart Cities (edx)	In this architecture course, you will learn the basics of information cities and urban science research, as well as how dynamic behavior and citizen-driven learning differentiate the responsive city from the smart city. This course is part of the "Future Cities" XSeries	https://sce.ethz.ch/en/programmes-and-courses/angebot-nach-cluster/environment-infrastructure-architecture.html?polycourseId=1555
3			Future Cities (edx)	A first course to understand a city's people, components, functions, scales, and dynamics, as precondition for its sustainable design and management	https://sce.ethz.ch/en/programmes-and-courses/angebot-nach-cluster/environment-infrastructure-architecture.html?polycourseId=1553
4			MAS ETH in Spatial Planning (MAS ETH SP)	The MAS Programme in Spatial Planning of the ETH Zurich focuses on the design and use of our living environment and the social, economic, and ecological processes involved. In the foreground of this course of studies is planning as an approach for anticipating solutions to problems in the area of spatial development. Theories and models of spatial development are presented from various scientific disciplines and methods of spatially relevant sectoral planning	https://sce.ethz.ch/en/programmes-and-courses/angebot-nach-cluster/environment-infrastructure-architecture.html?polycourseId=6

Order	School/Institute	Department/center/lab	Courses	Introduction	Website
5			Geo.BigData (science)	In diesem Modul beleuchten wir die Rolle der Geoinformatik im Zusammenhang mit den Big Three des Data Science. Sie lernen wie Big Data mit einem GIS-Werkzeug (QGIS) kombiniert werden kann und die Möglichkeiten der Analyse geographischer Daten mittels Methoden des Machine Learning	https://sce.ethz.ch/en/programmes-and-courses/angebot-nach-cluster/environment-infrastructure-architecture.html?polycourseId=1684
6			GITTA—Geographic Information Technology Training Alliance	GITTA is a project that offers free e-learning content through the creative commons license. The following topics are covered: GI-systems, data capture, database management and systems, spatial modeling, spatial analysis, data presentation	https://sce.ethz.ch/en/programmes-and-courses/angebot-nach-cluster/environment-infrastructure-architecture.html?polycourseId=1543
7	Harvard University	Graduate School of Design	Spatial Analysis and the Built Environment	This course provides first-semester urban planning students with the graphic and technical skills needed to reason, design, and communicate these processes with geospatial data. This knowledge will be embedded within a larger critical framework that addresses the cultural history of categorization, data collection, and cartography as tools of persuasion for organizing space	https://www.gsd.harvard.edu/course/spatial-analysis-and-the-built-environment-fall-2019/
8			Digital Media: Manipulations	This course is an introduction to fundamental concepts, techniques, and methods in digital design with a focus on reciprocal processes of translation between digital media and material artifacts	https://www.gsd.harvard.edu/course/digital-media-manipulations-fall-2019/

Order	School/Institute	Department/center/lab	Courses	Introduction	Website
9			Digital Media: Composition	This course proposes a conceptual opposition between "filter" and "fill" to investigate the ways image analysis techniques augment topics in architectural composition. In the context of this course, "filters" consist of processes designed to subtract data from images to render information legible, and "fills" are processes that add data to create content. Unpacking the inner workings of processes—such as segmentation, seam carving, and deconvolution—reveals intellectual and aesthetic dispositions behind popular design practices	https://www.gsd.harvard.edu/course/digital-media-composition-fall-2019/
10	Massachusetts Institute of Technology	Department of Urban Studies and Planning	Urban Science in Practice	The class introduces participants to the practice of Urban Science in the public sector, private sector, and civil society. It invites a series of practitioners from the field, who work with data analytic tools in urban planning to MIT to present and debate their work, exploring how the emerging field of Urban Science is affecting and changing traditional planning practice. The debates are structured around planning subfields—e.g. transportation, housing, urban design, community development, environmental planning, landscape, real estate, etc.—and invite presenters who represent both traditional subject area expertise (e.g., a city transportation director) and novel tools and methods that are being introduced to such fields	https://dusp.mit.edu/subject/spring-2020-11s952

Order	School/Institute	Department/center/lab	Courses	Introduction	Website
11			Applied Data Science for Cities: Hacking for Public Good	This course introduces computational thinking and applied data science practice related to urban domain. Students learn principles, tools, and techniques of using data for urban problem-solving through hands-on exercises in Python. The course also introduces unique aspects of urban data computing, such as heterogeneous data typology, real-world applications in cities, and socio-technical considerations involving ethics, fairness, and privacy. Students learn how to use data computation for public good by building applied data science projects relevant to urban problem-solving or/and computational social science	https://dusp.mit.edu/subject/spring-2020-11s187
12			Transportation Systems Analysis: Performance and Optimization	Problem-motivated introduction to methods, models, and tools for the analysis and design of transportation networks including their planning, operations, and control. Capacity of critical elements of transportation networks. Traffic flows and deterministic and probabilistic delay models. Formulation of optimization models for planning and scheduling of freight, transit, and airline systems, and their solution using software packages. User- and system-optimal traffic assignment. Control of traffic flows on highways, urban grids, and airspace	https://dusp.mit.edu/subject/spring-2020-11544

Order	School/Institute	Department/center/lab	Courses	Introduction	Website
13			Fundamentals of Spatial Database Management	The fundamentals of database management systems as applied to spatial analysis. Includes extensive hands-on exercises using real-world planning data. Introduces database management concepts, SQL (Structured Query Language), and enterprise-class database software. Same content as first half of 11.521. First half of term. Prerequisites: 11.204 or permission of instructor	https://dusp.mit.edu/subject/spring-2020-11523
14			Big Data, Visualization, and Society	Studies data visualization as a way for architects, planners, and policy experts to communicate with the public. Develops technical skills to work with big data to answer or expose urban issues, which include cleaning and aggregating data in Python, D3, and other web-based visualization software, and accessing APIs to download data. Students work with a big data set in a particular urban area and use the data to answer a policy question. Students taking graduate version complete additional assignments	https://dusp.mit.edu/subject/spring-2020-11454
15			Tools for Analysis: Design for Real Estate and Infrastructure Development	Introduction to analytical tools to support design and decision-making in real estate, infrastructure development, and investment. Particular focus on identifying and valuing sources of flexibility using "real options," Monte-Carlo simulation, and other techniques from the field of engineering systems. Integrates economic and engineering perspectives, and is suitable for students with various backgrounds. Provides useful preparation for thesis work in the area	https://dusp.mit.edu/subject/spring-2020-11434

Order	School/Institute	Department/center/lab	Courses	Introduction	Website
16			Tools and Techniques in Urban Economic Development Planning	Introduces a suite of tools representing the basic set of practices used in the development field. Presents a wealth creation framework that focuses on place, improving livelihoods, incentivizing collaboration, creating multiple forms of wealth, and promoting local ownership. Students work with web-based tools designed for use in a professional setting. Discussions are based on results from tools, their interpretation, and their meaning. Relevant to all students interested in the structure and function of local, state, national, and international economic contexts.	https://dusp.mit.edu/subject/spring-2020-11407
17			Data Science and Machine Learning Principles for Real Estate	Introduces students to data sources and science techniques for understanding real estate. Covers the foundations of data analytics. Includes a survey of machine learning methods and its applications to real estate development and financial analysis	https://dusp.mit.edu/subject/spring-2020-11321
18			Digital City Design Workshop	The Digital Revolution is changing the way we live today as radically as the Industrial Revolution did almost two centuries ago. As urbanization accelerates across the world, digital media and information technologies hold huge potential for understanding, designing, and managing cities. This seminar looks at issues faced in three sites that are make available to the class by the sponsors of the Senseable City Lab. Students will conduct and present background research, identify relevant questions, develop project ideas, and evolve them to a detailed set of digital technology and design scenarios	https://dusp.mit.edu/subject/spring-2020-11320

Order	School/Institute	Department/center/lab	Courses	Introduction	Website
19			Introduction to Spatial Analysis	Practical introduction to spatial analysis and geographic information systems (GIS). Examines how geography is represented digitally and how nonrandom distributions of phenomena as diverse as poverty and scenic resources can be better understood by examining their spatial characteristics	https://dusp.mit.edu/subject/spring-2020-11205
20			Urban Planning and Social Science Laboratory	An introduction to the research and empirical analysis of urban planning issues using geographic information systems. Extensive hands-on exercises provide experience with various techniques in spatial analysis and querying databases. Includes a small project on an urban planning problem involving the selection of appropriate methods, the use of primary and secondary data, computer-based modeling, and spatial analysis	https://dusp.mit.edu/subject/spring-2020-11188-0
21			Data and Society	Introduces students to the social, political, and ethical aspects of data science work. Designed to create reflective practitioners who are able to think critically about how collecting, aggregating, and analyzing data are social processes and processes that affect people	https://dusp.mit.edu/subject/spring-2020-11155

Order	School/Institute	Department/center/lab	Courses	Introduction	Website
22	The Queensland University of Technology	QUT Design Lab	Courses in the Design and Technologies of Tomorrow Research Program	The Design and Technologies of Tomorrow Research Program fosters innovation and experimentation with interactive and design technologies, including virtual and augmented reality, 3D printing, rapid prototyping, and CAD. We foster research related to innovative design manufacturing approaches and design through making, with our on-site fabricator, maker-spaces, and digital design studios engaging students, industry, and the broader public with design technologies	https://research.qut.edu.au/designlab/programs/
23	The UKRI-ESRC and the University of Glasgow	Urban Big Data Centre	Courses in MSc in Urban Analytics	Around the world, city governments are realizing the growing importance of harnessing the power of urban big data. This program will provide students with the knowledge and skills to design and conduct appropriate analyses, and experience of working with cutting-edge data sets	https://www.ubdc.ac.uk/education-and-events/education/msc-programmes/urban-analytics/
24			Courses in MSc in Urban Transport	In addition to learning about core transport planning and modeling approaches, a variety of practical skills sought after by employers are covered in the program such as working with geographic information systems (GIS), data science (using R), and statistical data analysis	https://www.ubdc.ac.uk/education-and-events/education/msc-programmes/urban-transport#testimonials

Order	School/Institute	Department/center/lab	Courses	Introduction	Website
25	University of California, Berkeley	The Department of City and Regional Planning	Principles of Computer Aided Architecture Design	This course introduces students to Architecture's New Media; why and how computers are being used in architecture, and what are their current and expected impacts on the discipline and practice of architecture. Topics include presentation and re-presentation (including sketching, drafting, modeling, animating, and rendering); generating design solutions (including generative systems, expert systems, genetic algorithms, and neural networks); evaluation and prediction (using examples from structures, energy, acoustics, and human factors); and the future uses of computers in architectural design (including such topics as construction automation, smart buildings, and virtual environments). The laboratories introduce students to REVIT, a state-of-the-art architectural software, including drafting, modeling, rendering, and for building information modeling	http://guide.berkeley.edu/courses/arch/

Order	School/Institute	Department/center/lab	Courses	Introduction	Website
26			Workshop in Designing Virtual Places	This course introduces students to designing web-accessible, Multi User, Virtual Environments (MUVEs), inhabited through avatars. Such worlds are used in video games and web-based applications, and are assuming their role as alternative "places" to physical spaces, where people shop, learn, are entertained, and socialize. Virtual worlds are designed according to the same principles that guide the design of physical spaces, with allowances made for the absence of gravity and other laws of nature. The course combines concepts from architecture, film studies, and video game design. It uses a game engine software and a modeling software to build, test, and deploy virtual worlds	http://guide.berkeley.edu/courses/arch/
27			Special Topics in Digital Design Theories and Methods	Topics cover advanced and research-related issues in digital design and New Media, related to architecture. For current offerings, see department website	http://guide.berkeley.edu/courses/arch/
28	University College London	The Bartlett Centre for Advanced Spatial Analysis	Courses in MSc in Smart Cities and Urban Analytics	The course builds on the need for a skill set in programming, spatial data capture, and the ability for urban analysis with an understanding of the theory and context to urban systems	https://www.ucl.ac.uk/bartlett/casa/programmes/msc-smart-cities-and-urban-analytics
29			Courses in MSc in Spatial Data science and Visualisation	A unique focus on analysis, mapping, and visualization, pulling together the latest research in urban form, functionality, and communication	https://www.ucl.ac.uk/bartlett/casa/programmes/msc-spatial-data-science-and-visualisation

Order	School/Institute	Department/center/lab	Courses	Introduction	Website
30			Connected Environments	Introduction to the "learn, build, critique" approach to be used throughout the course and the building blocks of creating a connected environment. At the end of this module we will have built our first shared "connected environment" that you will curate throughout the program	https://www.ucl.ac.uk/bartlett/casa/programmes/msc-connected-environments
31			Mobile Systems and Interactions	Gain exposure and understanding of what makes a good mobile application, and develop the skill set to design and build a mobile interfaces and applications	https://www.ucl.ac.uk/bartlett/casa/programmes/msc-connected-environments
32	University of New South Wales	The Faculty of the Built Environment	Digital Cities	This course explores the breadth of data available to urban policy makers, using recently completed and indeed "live" projects being undertaken within City Futures Research Centre and Built Environment more widely	https://www.be.unsw.edu.au/digital-cities
33			GIS and Urban Informatics	An introduction to Geographical Information Systems (GIS) and their applications in urban studies, planning, public management, public health, environment planning, and business contexts. A solid understanding of fundamental concepts, principles, and functions of GIS, and of types of spatial data, their entry, analysis, and display into a GIS. Overview of technical and institutional issues in GIS development	https://www.be.unsw.edu.au/gis-and-urban-informatics

Order	School/Institute	Department/center/lab	Courses	Introduction	Website
34	University of Oxford	The Oxford Internet Institute	Courses in MSc in Social Data Science	The MSc in Social Data Science is designed for students with core quantitative skills who wish to develop their skills for analyzing structured and unstructured data using advanced computational techniques such as machine learning. Theses in Social Data Science might develop new computational approaches for analyzing human behavioral data and/or apply such approaches to answer a social science question	https://www.oii.ox.ac.uk/study/msc-in-social-data-science/?faqs
35			Courses in MSc in Social Science of the Internet	The MSc in Social Science of the Internet is designed to contribute to the education of current and future researchers, policy makers, analysts, and practitioners from both public and private sectors, providing them with an in-depth understanding of the social science concepts, theories, methods, and principles to carry out innovative, high-quality research, analysis, and policy formulation	https://www.oii.ox.ac.uk/study/msc-in-social-science-of-the-internet/
36	University of Southern California	the Viterbi School of Engineering and the Dornsife College of Letters, Arts and Sciences	Courses in the Master of Science in Spatial Data Science	Geospatial data accessibility, spatial decision support systems, and geospatial problem-solving environments are revolutionizing most industries and disciplines, including health care, marketing, social services, human security, education, environmental sustainability, and transportation. Spatial data science professionals draw upon engineering, computer science, and spatial sciences principles to solve data-intensive, large-scale, location-based problems	https://viterbigradadmission.usc.edu/programs/masters/msprograms/data-science/ms-spatial-data-science/

Order	School/Institute	Department/center/lab	Courses	Introduction	Website
37	University of Warwick	Centre for Interdisciplinary Methodologies	Urban Analytics and Visualisation	Our unique MSc develops both the practical and theoretical skills needed—such as data analytics, urban theory, and visualization techniques—to tackle these challenges, combining practice with cutting-edge theoretical and methodological understanding of urban systems	https://warwick.ac.uk/fac/cross_fac/cim/apply-to-study/masters-programmes/urban-analytics/
38			Digital Media and Culture	It gives students a critical and practice-based understanding of how digital media and culture is being transformed by networks, algorithms, and software by memes, trolls, likes, and links, by uploads and downloads, by big data, personal data, and trash	https://warwick.ac.uk/fac/cross_fac/cim/apply-to-study/masters-programmes/digital-media-culture/
39			Big Data and Digital Futures	This course responds directly to the growing demand by employers for a new generation of postgraduates who can critically engage with big data both theoretically, methodologically and practically	https://warwick.ac.uk/fac/cross_fac/cim/apply-to-study/masters-programmes/big-data-digital-futures/
40	Wageningen University & Research and Delft University of Technology	Amsterdam Institute for Advanced Metropolitan Solutions	Courses in Metropolitan Analysis, Design and Engineering	MSc MADE focuses on our cities and metropolitan regions, which face the challenges of sustainability and quality of life in a fast urbanizing world. Issues of mobility and logistics, water and waste management, energy and food security, health and well-being are at risk	https://www.ams-institute.org/education/msc-made-program/

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