"AI Urban Space: Transformations, Trends, and Planning Responses": An Academic Dialogue

Authors

Otthein Herzog, YUAN Feng, WANG Xingping, LONG Ying, ZHANG Xiaochun, HUANG Jingnan, YANG Junyan, ZHANG Shanqi, ZHEN Feng, YAN Longxu

Abstract / Editor's Note

New-generation artificial intelligence (AI) is reshaping human socio-economic activity with unprecedented depth and breadth and is becoming deeply embedded in urban spatial systems. AI is emerging as a core force shaping future urban form, governance models, and rules of operation. As cities move from conventional "smart cities" toward more deeply intelligent "AI cities," a key theoretical issue and contemporary challenge for planning is how algorithms, computing power, and data will restructure urban space, how the evolution of such space can be anticipated, and how planning should respond. To address these questions, the editorial office invited ten experts to join an academic dialogue on "AI urban space: transformations, trends, and planning responses," focusing on urban cognition, virtual-real space, infrastructure, economic and social relations, and planning governance. Their main views are summarized below.

First, urban cognition and planning methods are changing. AI first changes how cities are perceived. Cities are becoming complex systems that can be sensed in real time, dynamically simulated, and intelligently inferred. YUAN Feng argues that the key to the AI city lies in moving from tool invocation to autonomous inference, enabling planners and agents to jointly formulate questions, organize simulations, and verify results. He further proposes a three-layer spatial methodology of hyper-simulation, hyper-mapping, and hyper-coupling, emphasizing parallel simulation of multiple urban systems and real-time bidirectional mapping between physical and digital spaces. Otthein Herzog, starting from urban digital twins and large language models, suggests that future planning will need multimodal agents and feedback mechanisms to manage the multi-actor, multi-objective, and multi-scalar complexity of cities. AI can improve planning efficiency while also shifting planning methods from experiential judgment and single-factor analysis toward systemic inference and collaborative decision-making.

Second, the object of urban space is expanding from physical space to a virtual-real composite system. A major change in AI cities is the expansion of the planning object itself. Cities are composed not only of land, buildings, roads, and facilities, but also of data, models, algorithms, rules, and digital scenes. YANG Junyan proposes that cyber cities are not digital replicas of physical cities; rather, they co-evolve with real cities through element connection and bidirectional feedback. Based on Shenzhen's digital-twin practice, ZHANG Xiaochun shows that digital twins are supporting spatial planning in its shift from fragmented and isolated planning to whole-domain coordination, and from single physical-space provision to synchronous provision of virtual and real spaces. Shenzhen is exploring coordinated integration between general large models and domain-specific professional models to realize dynamic and precise cross-domain inference.

Third, new infrastructure is moving cities from planar order toward three-dimensional coordination. The combination of AI with low-altitude economy, autonomous driving, smart logistics, and other new scenarios is changing how urban infrastructure is organized. HUANG Jingnan argues that low-altitude

infrastructure is characterized by the isomorphism of physical facilities and information networks; take-off and landing sites, route networks, communication and navigation, micro-meteorological environments, building heights, and spatial rights all need to be assessed within a unified framework. LONG Ying focuses on residential-area design and examines how large models can identify spatial problems in existing residential areas and translate new lifestyles such as unmanned delivery, low-altitude logistics, and robotic services into concrete residential-space prototypes. Ultimately, the AI city will move from clouds and platforms into blocks, communities, rooftops, roads, and everyday living scenes.

Fourth, economic space and social relations are being reorganized by algorithms. AI's urban impacts are also reflected in the restructuring of economic and social space. WANG Xingping argues that computing power, data, algorithms, and platforms are forming a new industrial geography; agriculture, manufacturing, and services are also being spatially reorganized through automation, while new regional inequalities and risks of digital marginalization may emerge. From the perspective of human-land-algorithm coordination, ZHANG Shanqi and ZHEN Feng point out that AI also brings algorithmic bias, privacy exposure, and spatial homogenization, making the AI city a new issue of public governance.

Fifth, planning governance must move from static control toward dynamic adaptation. In the face of the complex transformations of AI cities, the logic of traditional planning governance also needs to be updated. YAN Longxu argues that AI cities challenge traditional planning at three levels: macro spatial structure, meso functional layout, and micro spatial use. Central-place systems become more dynamic, functional boundaries become blurred, and spatial uses become more composite and flexible. Future planning must strengthen its capacity to identify, regulate, and guide dynamic processes and must build new institutional interfaces between technological evolution and public value.

The AI city presented in this dialogue is a complex system involving urban cognition, spatial objects, infrastructure, economic and social relations, and governance logics. AI requires algorithms and computing power, but it also requires public value and professional judgment; it requires digital space, but must also respond to real life. The responsibility of the planning discipline is to return AI to the basic questions of urban development: how cities operate, how space is organized, and whom technology ultimately serves.

Keywords

AI urban space; AI city; urban digital twins; large language models; cyber city; low-altitude infrastructure; spatial planning governance

Urban Digital Twins and LLMs: Implications for Planning Real Cities

Otthein Herzog (Foreign Member of the Chinese Academy of Engineering; Member of the National Academy of Science and Engineering, Germany; Professor at Tongji University; Professor at the University of Bremen, Germany)

A city, or part of a city, can be understood as a long-lived socio-technical system whose evolution is shaped by diverse interests and interdependencies. These include the spatial embedding of the planning object within larger hierarchies such as the city, state, or transport system, with increasingly important relationships to neighboring regions and to the third dimension; citizen and governance demands and resources concerning mobility, logistics of goods, energy, water and data, industrial and business development, sustainability, resilience, health, safety, and security; and historical experiences, infrastructures, existing values created by earlier decisions, and recent issues.

A city can therefore also be viewed as an interactive entity within a complex network of goals and interdependencies. To handle this complexity, urban planning and management work on at least two time scales and across the structural and dynamic dimensions of the city. Long-term urban planning starts from a given moment and a defined future horizon, seeking to create the potential for future infrastructure development under goals such as attractiveness to citizens, business, and tourism; financial, ecological, and capability-related sustainability; adaptability to future ideas, innovations, and opportunities; and resilience to a broad range of possible threats. Almost real-time operational planning, monitoring, and control focuses on subsystems and their interactions with important parameters, based on IoT data management and related AI analytics.

Although these two layers can be studied largely independently, their interrelationships must also be examined and managed. Statistics and operational issues observed through IoT and other operational data can improve urban planning, while knowledge captured at the planning level can be intelligently reused for operational tasks.

To capture the full range of city-planning aspects, models are needed that go beyond maps and data warehouses. Digital twins have already been used successfully in many individual urban-planning tasks. AI-based digital twins, together with data-exchange and simulation infrastructures, facilitate the modeling of real-world aspects and their interdependencies. Digital models can be implemented within a broad framework of digital-twin core conceptual models and services, as defined by the international industry IoT consortium: a digital twin is a virtual representation of real-world entities and processes, synchronized at a specified frequency and fidelity; digital-twin systems transform business by accelerating holistic understanding, optimal decision-making, and effective action; digital twins use real-time and historical data to represent the past and present and simulate predicted futures; and they are outcome-driven, tailored to use cases, powered by integration, built on data, guided by domain knowledge, and implemented in IT/OT systems.

The set of technological conceptual models known as the digital-twin core focuses on interoperability among data and computational models, as well as metadata, preprocessing, dataflow, and validation models. It offers an impressive picture of the highly complex technological environment of digital twins from the perspective of object-oriented analysis and design.

This perspective has been broadened by the advent of large language models (LLMs), which already play an important role in urban planning. More recently, LLMs have been generalized into agentic AI systems that can support multimodality, knowledge acquisition, plan validation, simulation, and decision-making. This technology makes it possible to create frameworks for urban-planning agentic social AI systems that integrate established multi-agent-system technologies with multimodal LLMs. Such frameworks provide a flexible, modular, and extendable approach for building distributed systems of cooperating and competing agents, thereby capturing the interdependencies among relevant urban aspects within a distributed agentic social AI system.

For urban-planning tasks, such an agentic social AI system can model relevant static urban structures, necessary urban dynamics, and the rules, demands, and contributions of urban stakeholders. It also suggests an interactive workflow with feedback cycles and plan validation. The aim is not to replace human planners, but to provide intelligent support in a cooperative and interactive manner through multimodal communication such as maps, images, reports, and voice.

The goal of such a planning cycle is to develop an urban digital twin that provides the necessary static and dynamic plan details for subsequent implementation. It should balance the many requirements arising from existing planning knowledge, technological constraints, administrative regulations, and requests from virtual and later human stakeholders. This iterative process includes citizen requests, regulations, financing constraints, and living and working conditions. It can also identify and consolidate interdependencies across planning aspects, for example by balancing citizen demands with land use, roads, mobility, energy, water, parks, resilience, and population health. Static structural plan elements should therefore be completed first as a basis for subsequently adding dynamic elements for process-oriented validation and simulation.

In a further step, this preliminary urban digital twin can be validated and improved through LLM-based stakeholder models, implemented as argumentative digital twins supported by specialized multimodal agentic AI models. These models can introduce specific and even antagonistic aspects into plan creation and negotiation, together with human behavioral models. Expensive and time-consuming citizen contributions can therefore be considered at later stages, when real people are invited to critique the plan.

Such systems also enable simulation-based evaluation of the operational feasibility of urban plans. They can assess IoT architecture options, including data distribution and governance, scalability, robustness, resilience, and openness to future innovation, in the operational execution of plans. They can also address semantic issues in enabling cooperation or competition among very large numbers of digital twins in operational settings.

The idea of urban digital twins implemented by a society of multimodal LLM-based agents - an agentic social AI system - clearly extends the original definition of a digital twin in terms of interoperability and complexity. Given the complexity of cities and urban planning, however, the planning field will need such a framework to address the complexity of planning livable cities. Such an urban digital twin can also serve as a framework for real-time operational planning, monitoring, and control of urban subsystems and their interactions.

The Era of Urban Super-Agents Driven by Speculative Intelligent Space

YUAN Feng (Dean and Distinguished Professor, College of Architecture and Urban Planning, Tongji University)

New-generation AI is moving beyond the boundaries of instrumental thinking. It is shifting from efficiency assistance to the reshaping of cognitive and intellectual modes, while becoming deeply embedded in the entire process of intelligent urban space, including many production, living, and ecological scenes. As philosopher Yuk Hui has suggested, humanity is moving from the humanist figure of homo faber toward homo sapiens and even homo deus. "Human-agent-nature" relations are now reshaping the meaning of the city on more equal terms. The core question of the AI City is therefore no longer simply how to make the city more intelligent, but how to reconstruct cognition, discover patterns, and create futures. This is not a matter of fitting a luxurious saddle to a carriage; it is a paradigm shift into the age of the automobile.

1. From autonomous invocation to intelligent computational inference: urban intelligence under human-machine co-governance

In traditional planning and design, simulations of wind environment, pedestrian flows, energy consumption, light, sound, heat, traffic flow, and emergency evacuation are discrete and expert-driven.

Planners must specify software, configure parameters, and connect data one by one. This "tool jungle" makes multi-objective coupling extremely difficult and has long blocked holistic insight across scales and disciplines.

Our direction is to build an "autonomous inference - research agent" architecture. Through the semantic-understanding capacity of large models, distributed open-source simulation-engine clusters on GitHub can be invoked directly, allowing AI to search, match, and combine the most suitable simulation tools according to design semantics, while verifying reliability through human-machine question-and-answer processes. This enables a leap from "specifying tools" to "autonomous pathfinding." Research workflows will no longer be centered on software, but on problem semantics. Tools are decoupled, capabilities are aggregated, and urban planning reaches a methodological inflection point of qualitative leap. Collaboration between planners and AI is no longer simply task delivery; it is joint questioning.

The technical core of this paradigm can be summarized in three layers: the "data + knowledge" layer, which integrates multi-source urban spatiotemporal data, including remote sensing, IoT, mobile signaling, BIM/CIM, and historical planning archives, with domain knowledge graphs such as standards, mechanism models, and design experience; the "invocation + algorithm" layer, which couples simulation engines, generative models, optimization solvers, and explainable logical reasoning including causality, rules, and ethical constraints; and the "workflow intelligent driving" layer, which provides programmable, traceable, and verifiable agent pipelines for concrete design and research problems.

2. Urban space as the core scene of intelligent space: hyper-simulation, hyper-mapping, and hyper-coupling

If the core of "smart space" is data visualization and operational monitoring, the core of the AI city is generation, decision-making, and co-evolution. I use three progressive concepts to summarize its spatial methodology.

Hyper-simulation breaks through closed simulations of single physical processes and establishes cross-domain parallel simulations of multiple urban systems, scales, and actors. It allows physical urban spaces such as autonomous-driving corridors, low-altitude logistics networks, and intelligent-response infrastructure to be simulated in resonance with human behavioral flows, energy flows, and information flows within the same engine.

Hyper-mapping breaks through one-way "physical-to-digital" digital twins and establishes bidirectional, real-time, semantic-level mapping between physical and digital space. Urban digital space is no longer merely the "shadow" of physical space; it becomes a prefigurative field for physical spatial evolution. Planning schemes first take shape, are tested, and are contested in digital space, and are then fed back to guide construction and transformation in physical space.

Hyper-coupling breaks through the separation of disciplines and systems, enabling transport, energy, ecology, society, economy, and governance to be deeply coupled at the algorithmic level. The siting of a low-altitude logistics corridor is simultaneously a noise-governance issue, an industrial-space issue, and a social-equity issue. AI gives us, for the first time, the capacity to handle such inherently non-decomposable complexity within a single decision model.

3. Responses from the planning and architecture disciplines

Facing this transformation, planning and architecture need to do three things. First, they must reconstruct a knowledge system for coexistence with super-agents and incorporate algorithmic literacy, simulation engineering, and agent collaboration into the core capacities of planners and architects.

Second, they must build open digital-intelligence infrastructure, promoting shared urban simulation-engine libraries, knowledge graphs, and data interfaces, and avoiding repeated reinvention by individual teams. Third, they must reshape an ethical position for the post-humanist era. As AI autonomy expands rapidly, planners must remain alert to algorithmic black boxes, digital divides, and new questions of spatial justice. The more autonomous technology becomes, the more important planners' value judgments will be.

An intelligent city is not a city that passively adapts to technology, but one that co-evolves with technology. The mission of planning is to reopen, on the basis of hyper-simulation, hyper-mapping, and hyper-coupling, the fundamental question of why future cities should become better.

AI and the Production and Reorganization of Economic Space

WANG Xingping (Professor, School of Architecture, Southeast University; Director, International Cooperation Research Center for Sustainable Industrial Park Development and Planning, Southeast University)

AI, or artificial intelligence, is a technological system that simulates, extends, and expands human intelligence, enabling machines to complete complex tasks that normally require human intelligence. AI technology and industry can be divided intuitively into two categories: the development of AI software and hardware itself, and the integration and application of AI across industries. Human society is entering a new era of AI civilization. Although AI development and application are still in a "fetal stage" and are mainly entering society through comprehensive automation, while deep autonomy and replacement of human intelligence are not yet fully realized, even this seemingly early stage has already profoundly "produced" and "restructured" economic space. This includes both the physical and digital spaces of the AI industrial chain itself and the ubiquitous economic spaces into which AI applications are penetrating.

China attaches great importance to this historical opportunity and is at the forefront of global AI development. It has successively issued policy documents such as the New Generation Artificial Intelligence Development Plan (2017), the Interim Measures for the Management of Generative Artificial Intelligence Services (2023), and the State Council's Opinions on Deeply Implementing the "Artificial Intelligence Plus" Initiative (2025). These documents set goals for the AI core industry to exceed RMB 1 trillion by 2030 and to drive related industries beyond RMB 10 trillion, forming a comprehensive guidance system across technological research and development, infrastructure, industrial implementation, and governance norms.

At present, AI's impact on economic space is emerging in three main ways.

1. The AI industrial chain creates new types and patterns of economic space

AI software and hardware production is creating and restructuring industrial geography and the logic of value distribution. On the one hand, AI research, development, and manufacturing industries are emerging and concentrating in urban space, giving rise to new economic spatial forms such as AI communities and OPC communities. On the other hand, AI preferences are reshaping the geography of related software and hardware industries. On the hardware side, the massive computing demand of large-model training is driving hyperscale data centers toward energy-rich and cool-climate regions such as Guizhou and Ulanqab. Advanced-process chip manufacturing is highly concentrated around leading enterprises, producing a broad spatial division between "computing-power core areas" and "computing-power peripheral areas." On the software side, open-source code communities and cloud model-service platforms (MaaS) break physical spatial limits, enabling developers to participate in AI value creation from anywhere and forming a borderless digital innovation space of virtual-real interaction.

2. AI applications restructure ubiquitous economic space

The automated penetration of AI promotes coexistence and collaboration between humans and humanoid robots, systematically reorganizing the traditional spatial forms of the three major sectors and producing new economic-spatial scenes and modes. In agriculture, AI drones for field inspection, soil-moisture monitoring, and pest prediction allow a single technician to manage thousands of mu of farmland, shifting production space from dispersed family farms toward centralized digital farms. In manufacturing, AI visual inspection, predictive maintenance, and intelligent scheduling are entering production and management processes comprehensively, reducing dependence on traditional labor and giving rise to large-scale "lights-out factories" and "unmanned parks," while pushing manufacturing activities toward regions with better digital infrastructure and lower labor costs. In services, telemedicine, AI educational tutoring, and intelligent customer service decouple service provision from physical settings in time and space, enabling residents in remote areas to access medical and educational resources comparable to those of first-tier cities. This narrows urban-rural gaps in service accessibility, but also causes some traditional service jobs in urban centers to contract. AI thus promotes a new pattern in which virtual agglomeration and physical dispersion coexist and interact.

3. AI's particular preferences intensify regional unevenness in economic space

The efficiency gains brought by AI currently concentrate mainly in platform enterprises and regions that possess data, computing power, and algorithms. Beijing, Shenzhen, Silicon Valley, and other regions with computing infrastructure and data resources further strengthen their positions as new AI growth poles. Meanwhile, peripheral regions with abundant energy resources and suitable climates also gain new opportunities for latecomer rise through the AI industry. Regions lacking these factors, however, face risks of digital marginalization. Ordinary workers and small and medium-sized producers receive a relatively low share of benefits, which may further reinforce the center-periphery structure among regional economic spaces and create risks of deconstruction and unreasonable reconstruction in interregional development relations.

The characterization of AI as being in a "fetal stage" means that its direction remains highly malleable. The introduction of automation is a necessary stage toward human-machine autonomous collaboration. AI's current restructuring of economic space contains opportunities to optimize resource allocation and narrow urban-rural service gaps, but it also brings challenges such as regional development imbalance. AI also changes the allocation of productive forces and the mode of human existence. Human-land relations expand into complex relations among humans, humanoid AI, and virtual-real two-dimensional spaces, thereby rewriting traditional production-city spatial relations. Guiding AI toward beneficial development cannot mean allowing technology to evolve spontaneously. It requires institutional design, including inclusive computing-power construction, cultivation of source ecosystems, and improved distribution mechanisms, as well as scientific planning guidance adapted to the laws of beneficial AI development. Only then can AI's spatial production process become more inclusive, allowing all people to share the dividends of technological development and enabling a rational construction of economic space in the AI era.

AI-use statement: This article was completed with AI-assisted writing. The author drafted the core views and main structure and provided key information; responsibility for the text rests with the author.

Residential-Area Design Empowered by Large Models: Problem Discovery, Trend Adaptation, and Practical Response

LONG Ying (Tenured Professor, School of Architecture, Tsinghua University)

New-generation AI technologies represented by large models are developing rapidly. Their outstanding natural-language understanding, cross-modal information processing, and logical reasoning capabilities provide new support tools for urban planning and spatial design. As basic spatial units of the city, residential areas involve complex information analysis and the integration of many elements, offering concrete scenarios for embedding large-model technologies in practice. My team is currently exploring three core links: discovering problems and extracting experience in existing residential areas, adapting to trends in new lifestyles, and responding through human-machine collaboration.

For problem discovery and experience extraction, we focus on identifying existing problems in residential areas and systematically refining spatial-intervention design methods. Previously, limited manual processing capacity made it difficult to analyze large volumes of unstructured case data quickly or to transform them into design references during early analysis. Large models, with their image-text understanding capabilities, now help break this processing barrier. By collecting extensive image and text materials from existing residential-area cases and setting explicit feature-extraction rules in prompts, we guide large models to analyze case data rapidly, automatically extract typical objects across dimensions such as building units, public space, green infrastructure, and traffic organization, and summarize their spatial pain points. We also conduct text analysis of residential cases, extract fine-grained design methods, and use text vectorization and clustering algorithms to reduce dimensionality and classify dispersed, non-standardized design-method texts. Combined with manual verification, this produces hundreds of design methods covering various spatial elements. Empowered by large models, this workflow can systematically transform massive case materials into structured "problem maps of existing residential areas" and corresponding "residential-area design-method sets," providing a rich and valuable strategy base for subsequent design work.

For trend adaptation, new technologies have generated emerging scenarios in residential areas, including robotic services, drone delivery, and autonomous-vehicle connection. How to respond to residents' new lifestyles has become an important consideration in design. Taking "low-altitude economy and smart logistics" as an example, we use large models' web-search and image-text analysis capabilities to conduct cross-scenario case analysis, collect recent technology implementation projects from the internet, and accurately summarize the spatial characteristics and mature patterns of new-technology applications in various open spaces. We then combine this with field research to assess the adaptability of these frontier technologies as they migrate into the physical space of residential areas, translating mature urban-space applications into residential-space prototypes. On this basis, we construct a trend-response scenario library covering public space, road facilities, and residential space, including scenarios such as drone logistics take-off and landing nodes and unmanned-vehicle delivery corridors. This enables residential-area spatial design to respond actively to emerging trends.

For practical response, large models are not only auxiliary analytical tools for early design, but also important means for deep involvement in scheme generation and evaluation. For specific residential-area design projects, site conditions, relevant policy texts, actual resident needs, the design-method set, and the trend-response scenario library can be entered into the model as knowledge inputs. Based on different design orientations, the large model can rapidly generate multiple differentiated residential-area design schemes, including written scheme explanations and design nodes. In evaluation, the model can simulate perspectives and demands of different groups based on predefined resident profiles, and conduct quantitative comparison and qualitative assessment of multiple generated schemes. The closed-loop practice of "survey-data analysis - multiple scheme generation - simulated evaluation feedback" demonstrates the great potential of large models in supporting residential-area design.

The disruptive technologies of the Fourth Industrial Revolution are exerting an unstoppable influence on the ontology of urban space and on planning methodology. New-generation AI is no longer merely an efficiency tool for processing data; it is becoming a powerful engine of generation and reasoning. As with earlier technological revolutions, the key is to embrace the technology early and make it useful for us. I therefore call on colleagues in urban-planning academia and practice to continue following technological development, integrate frontier technologies such as large models into all practical links of urban research and spatial design, and jointly explore new pathways for AI-empowered human-settlement construction.

Digital Twins Empowering Urban Spatial Planning in the New Era

ZHANG Xiaochun (Chairman, Shenzhen Smart City Technology Development Group; National Engineering Survey and Design Master; Professor-level Senior Engineer)

1. Main challenges for urban spatial planning in the new era

A new round of technological revolution represented by big data and AI is deeply reshaping economic society and urban operation. High-frequency functional renewal has become a major new characteristic, and urban spatial planning now faces three challenges: cross-level coordination, multi-professional collaboration, and adaptation to new quality productive forces.

First, the spatial baseline is unclear and digital space is discontinuous, making it difficult to support whole-domain, cross-scale planning coordination. Spatial data are dispersed across departments, with inconsistent spatiotemporal references, statistical standards, and attribute definitions. Data scales are fragmented across aboveground and underground, two-dimensional and three-dimensional, static and dynamic dimensions. Poor interoperability weakens whole-domain cross-scale coordination and intensifies conflicts among plans.

Second, vertical professional models are dispersed and independent, and large and small model technologies are fragmented, making it difficult to support precise cross-domain integrated inference. Professional models are often built independently according to their own business needs. Differences in data standards and spatiotemporal scales make integration difficult, and the underlying mechanisms of large models and traditional professional models are hard to align. This leads to mismatches in cross-domain functions and inaccuracies in cross-department decision-making.

Third, the traditional one-dimensional, static provision model of spatial planning cannot adapt to the deep integration of digital and physical development required by new quality productive forces. Strategic emerging industries such as the low-altitude economy, autonomous driving, and embodied intelligence urgently require both digital-space simulation and physical-space synchronized linkage.

2. Shenzhen's practice of digital twins empowering spatial planning

In the past three years, Shenzhen has carried out more than 450 digital-twin applications in urban construction, economic operation, and other fields, promoting whole-domain digital transformation. In urban spatial planning, it has empowered planning systematically through three aspects: a unified data base, key supporting technologies, and planning-application models.

First, Shenzhen has built a city-level unified digital-twin base to support multi-scale spatial-planning coordination. It has constructed a standard basemap system, a HarmonyOS-architecture perception network, and the SZ-IFC data-standard system; developed intelligent data governance and updating algorithms; implemented a mandatory BIM/CIM construction-application system; established cross-department data-coordination and updating mechanisms; and built a unified citywide spatiotemporal information platform. This has formed a territorial spatial data base integrating and dynamically updating more than 50 types of spatial data, including planning, land, and marine data. In recent years, Shenzhen's digital-twin base has supported more than 600 major projects, including citywide territorial spatial planning, rail-transit special planning, and the 2026 APEC main-venue area plan, enabling cross-scale integration from macro planning to area planning and individual projects.

Second, Shenzhen has built a layered and nested technology system of large and small models to realize cross-domain collaborative, dynamic, and precise inference. It has developed a large model for urban scientific computing, combined with a hyper-converged database, unified data standards, spatiotemporal scales, and model-mechanism standards, and created a collaborative inference architecture in which large and small models are nested. General and vertical professional models are integrated to replace traditional single-domain inference. For holiday traffic congestion, Shenzhen uses large models to assess non-routine influencing factors such as weather, scenic-area activities, control measures, and economic fluctuations, rapidly forecast regional traffic, and provide global optimization strategies. Small models focus on key sections and nodes, formulate optimal ramp and intersection-level schemes, and achieve simultaneous local and global optimization through nested spatiotemporal relations, significantly improving forecast accuracy and traffic-control effectiveness.

Third, Shenzhen has built a virtual-real model of "synchronous provision and co-frequency evolution" to meet the needs of new quality productive forces. In provision, relying on the digital-twin base, Shenzhen both allocates land for low-altitude economy, new energy, intelligent connected systems, and other new quality productive forces, and provides a unified and continuous citywide digital-twin space that supports embodied-intelligence simulation, virtual-real collaborative dispatch, human-machine collaboration, and other interactive needs. This realizes the transition from one-dimensional physical-space provision to synchronous virtual-real provision. In implementation, Shenzhen is planning and building several training grounds in Dapeng, Pingshan, and other areas, establishing a dynamic implementation chain of "virtual-space simulation and inference - training-ground testing and verification - generalized application in spatial planning." This enables virtual-real spatial symbiosis and co-frequency evolution, supporting rapid iterative upgrading of strategic emerging industries.

Shenzhen's practice shows that digital-twin technology can effectively support the transformation of urban spatial planning from "fragmented and isolated planning" to "whole-domain cross-scale coordination," from "single-department decision-making" to "multi-department collaboration," and from "single-dimensional one-time provision" to "virtual-real symbiosis and co-frequency evolution."

Constructing "Physical-Information" Urban Low-Altitude Infrastructure and Planning Responses

HUANG Jingnan (Professor, Department of Urban Planning, School of Urban Design, Wuhan University)

The rise of the low-altitude economy has triggered a wave of urban low-altitude infrastructure construction. The "physical-information" isomorphism of such infrastructure means that planning and construction must respond to complex urban environmental challenges, including deeply interwoven networks, complex spatiotemporal change, and rising resilience requirements.

In recent years, the increasing popularity of low-altitude aircraft represented by drones and electric vertical take-off and landing aircraft (eVTOLs) has driven the rise of the low-altitude economy and is transforming urban transport from traditional ground traffic toward a new form of integrated air-ground and vertically layered mobility. As the basic condition and key carrier for low-altitude economic development, low-altitude infrastructure is crucial.

The greatest difference between low-altitude infrastructure and traditional infrastructure is that it consists of two systems: the "physical" and the "information" systems. Physical facilities include visible entities such as take-off and landing sites and charging stations. Information facilities form an invisible digital network composed of communication and navigation systems. Only when both systems operate properly can the take-off, landing, and operation of aircraft be guaranteed. The mismatch of "sites without networks" or "networks without sites" is a common problem in low-altitude infrastructure planning.

The physical-information isomorphism of low-altitude infrastructure also means that its planning and construction face severe constraints from complex built environments. First, urban low altitude is not a homogeneous, static, two-dimensional extension, but a high-density and highly heterogeneous three-dimensional space. Staggered urban building clusters not only create direct physical resistance and line-of-sight obstacles, but also induce abrupt micro-meteorological changes such as urban canyon winds, wake vortices, and strong wind shear. Second, the operation of low-altitude aircraft relies heavily on invisible integrated communication-sensing networks. Dense reinforced-concrete media and high-frequency urban background noise cause signal attenuation, multipath reflection, and blind-zone fragmentation for communication and radar-monitoring beams in three-dimensional urban space. Finally, in the temporal dimension, urban low-altitude systems are continually subject to dynamic disturbances arising from human-land interaction. Under normal conditions, low-altitude logistics and instant-delivery flows closely follow human activity trajectories and show strong tidal fluctuations over time. Under extreme scenarios, such as ground-road disruption caused by meteorological disasters or large-scale emergency responses triggered by fires, low-altitude networks may be overloaded instantly and easily fall into local or even citywide paralysis.

The planning and construction of low-altitude infrastructure also face challenges from social regulation and neighborhood effects in human settlements. Conflicts over spatial-use rights are the most direct contradiction. Facilities such as take-off and landing points and charging stations often need to be deployed on rooftops, in community public spaces, or on building facades, overlapping with existing urban functions. Mechanisms for spatial ownership and benefit distribution urgently need to be clarified. At the same time, low-altitude aircraft enter residents' living areas at close range. Externalities such as flight noise, privacy and security risks, and falling-object hazards can easily touch the public's psychological safety threshold and raise questions of spatial-environmental justice.

In response to these new characteristics and challenges, urban spatial planning needs to adjust in four ways.

First, planning should move beyond ground-centered two-dimensional land-use thinking and build an integrated analysis method for aboveground, underground, airspace, and space-ground systems. Building height, roof load-bearing capacity, airspace availability, communication and navigation coverage, electromagnetic environment, and other factors should be incorporated into a unified framework, and multi-dimensional, multi-scale spatial-adaptation models should be established. With the latest AI algorithms and digital-twin platforms, take-off and landing-site selection and route-network layout can be optimized collaboratively, improving the coupling efficiency between low-altitude infrastructure and existing urban space.

Second, low-altitude take-off and landing facilities should be deeply integrated with urban scenarios and fields such as transport, medical care, emergency response, and logistics, forming intensive and composite facility-layout models. Superimposed spatial functions can enable flexible switching between ordinary and disaster-time functions: in normal times, such facilities can be integrated into commercial logistics systems to improve urban operating efficiency; during disasters, low-altitude aircraft can exploit their rapid response and route flexibility to undertake emergency tasks. Such mixed functional use can improve both urban spatial efficiency and system resilience.

Third, social acceptance and spatial equity should be included as core decision variables in facility siting. Quantitative methods should be used to evaluate social-impact factors such as noise exposure, privacy infringement, and safety risk, and multi-objective optimization models should be built to balance technical efficiency and social impact. This can reduce residents' psychological resistance to low-altitude facilities and prevent vulnerable communities from bearing disproportionate negative externalities.

Fourth, new mechanisms for coordinating airspace use should be explored. The embedding of low-altitude facilities makes spatial-rights relations increasingly complex, and spatial use is shifting from exclusive possession toward composite sharing. Cross-regional and cross-ownership coordination mechanisms for airspace use are therefore urgently needed. The definition, allocation, and transfer rules of airspace-use rights should be clarified, promoting a governance shift from "land property rights" to "spatial resources" and providing institutional safeguards for the orderly development of low-altitude infrastructure.

Interreflection and Symbiosis of Virtual and Real Cities: New Questions for the Planning Discipline

YANG Junyan (Professor, School of Architecture, Southeast University)

Globally, more than 200 million people now spend more time immersed in cyberspace than in real life. With the deep penetration of digital twins, AI, the metaverse, and related technologies, humanity is gradually constructing digital cyberspace in a full sense, and urban form is extending from the physical dimension into dual virtual-real dimensions. The discipline of urban planning must confront three new questions for future human settlements: the possible existence and construction mechanisms of future cyber cities; the interactive mapping mechanisms between cyber cities and real cities; and the elevation of digital technology from a planning tool to a digital urban-planning paradigm. Only by responding to these questions can urban planning adapt to the developmental needs of the digital-civilization era and realize the interreflection and symbiosis of virtual and real cities.

1. Cyber cities: foreseeable future urban forms and their different construction mechanisms from cities in the physical world

Cyber cities are not science fiction. They are the inevitable product of the deep integration of digital technology and human settlement needs, and their construction mechanisms differ fundamentally from those of physical cities. Physical cities are organized around the logic of material-space agglomeration, whereas cyber cities are organized around the agglomeration of data and relations. Relying on digital networks, algorithmic models, and virtual scenes, they break geographical limits and display borderless, iterable, and multidimensional characteristics. In essence, they extend and reconstruct social relations and activity needs in digital space, forming a new type of social space beyond geographical place.

This difference in construction mechanism gives the two kinds of city distinct core characteristics. The growth of physical cities is rigidly constrained by natural conditions and resource endowments, and their form-making is gradual and irreversible. Cyber cities, by contrast, are defined by rules. Their spatial form and functional layout can be quickly adjusted through algorithmic iteration, and they can simulate the evolution of physical cities, enabling "try before acting" virtual inference. Future cyber cities will by no means be digital replicas of material cities. They will be "second cities" with independent construction logics, capable of carrying new forms of virtual work, social interaction, and entertainment for all humanity, while also influencing physical urban operations through data feedback and forming a new pattern of bidirectional virtual-real empowerment.

2. Virtual-real interaction: connection, feedback, and evolution between cyber cities and real cities

The interactive mapping between cyber cities and real cities is not a simple virtual-to-real copy. Instead, deep integration is achieved through element connection, bidirectional feedback, and interactive evolution. The key lies in establishing mechanisms of virtual-real connection. The full digitization of physical urban elements is the foundation of interaction, while cyber cities use algorithmic optimization and scenario simulation to feed back into reality. In other words, social rules and functional inferences generated in virtual space can directly influence the evolution of physical cities.

As a complex mega-system and living organism, the city has its own laws of growth and evolution. Cyber cities are also complex mega-systems, with their own cycles of construction, growth, and evolution. Although the operating and evolutionary rules of the two are markedly different, countless virtual and real elements are connected. The regional culture, folk customs, and spatial genes of real cities strongly influence and constrain cyber cities, while cyber-city innovation and interaction directly feed back into the functional layout and facility operation of real cities. Virtual-real interactive mapping is therefore increasingly important, and the two systems are gradually forming their own mechanisms of coordinated evolution.

3. Paradigm transition: planning transformation from digital tools to a digital paradigm

The shift from digital tools to a digital paradigm is the core response of the planning discipline to the rise of cyber cities and an inevitable requirement of disciplinary transformation. For a long time, digital technology has played an auxiliary role in urban planning. Whether GIS mapping or data statistics, it has essentially provided technical support for traditional physical-space planning without breaking through the logic of physical-space dominance. The core of the digital paradigm is to treat digital space as a planning object as important as physical space, shift the focus of planning from spatial construction to rule design, and build a virtual-real collaborative planning system.

This paradigm upgrade contains three levels. First, the planning object expands from single material space to dual real-cyber space, bringing data rights confirmation, algorithmic ethics, and virtual-space boundaries into the scope of planning. Second, planning methods are renewed: experience-led planning gives way to technologies such as digital twins and urban large models, enabling virtual simulation, dynamic inference, and real-time optimization of planning schemes. Third, planning goals are elevated from spatial optimization toward virtual-real symbiosis. Planning must ensure the livability of physical cities while also considering the inclusiveness and security of cyber cities and avoiding algorithmic monopolies and digital enclave separation.

This is expressed through two pathways. The first is functional complementarity. Cyber cities undertake non-material functions of physical cities, such as remote work, online education, recreation, and social interaction, thereby easing spatial pressure on physical cities. Physical cities provide material carriers and real experience for cyber cities, compensating for the lack of authenticity in virtual space. The second is dynamic coordination. Through real-time data monitoring, cyber cities can anticipate operational risks in physical cities, such as traffic congestion, disasters, or facility leakage, and provide guidance in advance. Feedback from physical-city practice continuously improves cyber-city models and algorithms, forming a closed loop of perception, simulation, decision-making, and optimization.

4. Conclusion: virtual-real symbiosis and urban planning in the age of digital civilization

Cyber cities represent a paradigm upgrade in human settlement forms. Cyber-city planning is not a negation of traditional planning, but an extension of its disciplinary meaning. The core of future urban planning lies in grasping the intrinsic laws of virtual-real mapping and balancing technological rationality with humanistic value. Through rule design, planning should regulate the construction and operation of cyber cities; through interaction mechanisms, it should realize the coordinated evolution of virtual and real spaces. Planners need to move beyond tool thinking and reconstruct planning logic through a digital paradigm, combining the Eastern wisdom of "the unity of heaven and humanity" with digital technology. In this way, cyber cities and physical cities can jointly carry humanity's pursuit of a better life and lead urban planning into a new era of digital civilization.

"Human-Land-Algorithm" Coordination: Urban Spatial Restructuring in the AI Era

ZHANG Shanqi (Associate Professor, Provincial Key Laboratory of Urban AI and Green Human-Settlement Environment Construction, School of Architecture and Urban Planning, Nanjing University), ZHEN Feng (Professor, Provincial Key Laboratory of Urban AI and Green Human-Settlement Environment Construction, School of Architecture and Urban Planning, Nanjing University)

Technology has always been an important force driving the evolution of urban functions and the restructuring of space. New-generation AI technologies are moving cities from "digital governance" toward "autonomous governance." Unlike traditional smart-city technologies centered on sensing, transmission, cognition, and control, AI is represented by autonomous driving, low-altitude logistics, service robots, and generative planning agents. It has capabilities for predictive analysis, generative expression, and decision support, and is gradually becoming embedded in key links of urban operation. The city is no longer merely a spatial carrier that passively responds to external demand. It is evolving into a complex system that continually adjusts and self-optimizes under algorithmic drive. In this process, urban space is moving from a production system dominated by human-land relations toward a generative system of human-land-algorithm coordination, and its evolutionary logic will change fundamentally.

First, AI reshapes residents' spatial perception and decision-making through prediction and recommendation mechanisms. Traditional spatial cognition relies mainly on spatial elements, but with AI intervention, residents' understanding of the city is increasingly built on real-time data, algorithms, and agent recommendations. Autonomous driving and low-altitude logistics illustrate this transition. On the one hand, autonomous driving can reduce passengers' concerns about personal risks associated with unfamiliar drivers, and drone delivery can shorten delivery time and expand service radius, improving the accessibility and timeliness of urban services. On the other hand, system failures, falling accidents, unclear liability, and insufficient emergency response make technology itself a new source of safety anxiety. Spatial safety perception thus shifts from avoidance of single physical risks to multidimensional judgments involving algorithmic bias, privacy exposure, and technological trustworthiness. In addition, generative AI lowers the threshold for the public to obtain planning information and express spatial demands through natural-language interaction, allowing more direct participation in spatial cognition and discussion. Yet when individual experience is gradually replaced by algorithmic interpretation and personalized recommendation, spatial perception may be subtly guided by platform logic and capital orientation, thereby reshaping behavioral choices and spatial preferences.

Second, AI changes the production mode and organizational logic of urban space through generation and optimization mechanisms. Autonomous driving, unmanned delivery, and low-altitude logistics are restructuring road systems, parking structures, and warehouse-distribution nodes, pushing urban infrastructure from static allocation toward networked systems characterized by dynamic response and providing a more real-time and data-driven foundation for urban spatial organization. On this basis, generative AI is gradually entering planning design, scheme comparison, and public consultation, moving from auxiliary tool to co-generative subject of spatial schemes. This transformation greatly improves the efficiency of spatial production, but it also brings new structural risks. When models learn from and reproduce spatial samples with high visibility and high conversion rates, different areas may converge toward similar spatial forms and consumption scenes, leading to spatial homogenization and weakened locality. At the same time, AI's replacement of professional tasks in design, driving, and delivery extends spatial-production issues into questions of labor restructuring and social distribution.

Overall, AI's impact on urban space is moving from local embedding toward systemic restructuring. Its mechanism of action is expanding from efficiency improvement to the comprehensive reshaping of spatial organization, social relations, and governance structures. On the one hand, the integration of prediction, generation, and decision-making shifts urban operation from ex post response to ex ante anticipation and dynamic dispatch, providing greater foresight and adaptability for spatial planning and governance. On the other hand, risk transfer, blurred privacy boundaries, intensified spatial homogenization, and cumulative algorithmic bias show that the AI city does not necessarily lead to a better spatial order.

At present, AI technology is evolving rapidly while institutional provision lags behind. The tension between technological capability and public value is becoming increasingly prominent. Planning responses should not remain at the level of technical access and tool adaptation, but should move toward institutional and methodological reconstruction for governance scenarios. First, algorithmic rules, data flows, and platform mechanisms should be incorporated into spatial-planning analysis and control systems, extending the traditional planning paradigm centered on physical elements. Second, spatial monitoring and evaluation indicators for AI impacts should be developed to identify algorithm-driven spatial inequality and structural bias. Third, multi-agent simulation and generative models should be used to forecast spatial evolution under different paths of technological intervention and improve the foresight and resilience of planning decisions. Only by establishing effective interfaces between technological evolution and public value can AI become a key force for high-quality urban development and modernization of spatial governance.

Challenges for Planning in the Context of AI Cities

YAN Longxu (Associate Professor, College of Architecture and Urban Planning, Tongji University)

A new round of technological transformation centered on big data, AI, and computing-power infrastructure is moving cities from "smart cities" toward deeper "AI cities." In this process, technology is no longer merely a tool attached to urban operation; it is gradually becoming a foundational force that reshapes spatial structure, functional allocation, and urban operation. This section briefly discusses the planning challenges in terms of spatial structure, spatial layout, and spatial use.

1. Challenges for macro spatial-structure planning

At the macro scale, the core feature of AI and related technologies is that they significantly reduce the cost of factor flows, making flows faster and more convenient, and thereby shaking the center-periphery tree structure built on physical distance and transport costs.

In terms of centripetal forces, traditional urban economics holds that urban centers arise from scale effects and agglomeration economies created by spatial proximity. With the relocation of manufacturing, centers increasingly rely on producer services and high-end commerce, whose operation depends on face-to-face communication, diverse environments, and complex interaction networks. Yet remote collaboration, cloud computing, digital twins, and related technologies are weakening this reliance on proximity. New functions such as software development, AI applications, and data services can collaborate under distributed conditions, and their locational dependence on traditional centers is significantly reduced. Whether these functions continue to concentrate in a few advantaged nodes, forming new "digital centers," or disperse over wider areas will profoundly affect the evolutionary path of urban spatial structure.

In terms of centrifugal forces, central place theory rests on the constraints that geographical distance imposes on service areas, thereby forming a stable hierarchy. Under AI and the digital economy, however, producer services, online consumption, and the platform economy are increasingly freed from clear spatial service areas. Through digital platforms, urban nodes can serve national and even global markets, and their "market areas" are no longer constrained by physical distance. Nodes able to expand their service scope will therefore gain scale advantages beyond the traditional hierarchy.

When both centripetal and centrifugal forces are highly unstable, urban-rural systems and central-place systems will become more dynamic and complex. The key planning challenge is how to summarize new spatial-organization models, identify mechanisms of structural evolution, and form guiding macro frameworks under highly uncertain technological conditions. This will clearly depend on interdisciplinary research and long-term accumulation of experience.

2. Challenges to the idea of functional zoning in spatial layout

At the meso scale, the development of AI cities is challenging the spatial-organization idea centered on functional zoning. Modern planning systems emerged in the context of industrialization, based on the assumption that different functions have externality conflicts and that spatial separation improves efficiency and ensures safety. Thus, zoning systems for residential, industrial, commercial, and public-service uses have long constituted the foundation of spatial organization.

AI and related technologies, however, are promoting the recoupling of production and living functions. On the one hand, automation, intelligent manufacturing, and unmanned systems reduce industry's dependence on specific spatial conditions, weaken externalities such as pollution and noise, and make industrial areas lighter and less perceptible. On the other hand, remote work, the platform economy, and digital content production embed large amounts of production activity into residential and community spaces, giving living spaces production attributes. Meanwhile, the development of demand identification, instant delivery, and distributed service networks is pushing commerce, logistics, and public services down into life circles and community nodes. Cities are shifting from a system in which a few centers carry functions toward a multi-node and proximate service system.

Against the background of limited incremental space and solidified existing space, such functional reorganization poses practical challenges to planning. Existing zoning systems find it difficult to accommodate highly composite and dynamic functional combinations, while large-scale spatial adjustments are costly. It is therefore necessary to rethink the meaning of zoning, shifting from rigid separation toward a non-tree spatial organization that supports coexistence of multiple functions and emphasizes compatibility and flexibility. This is not only a question of form, but also a transformation of control logic.

3. Challenges for concrete spatial use and use control

At the micro scale, the most direct impact of AI cities lies in the restructuring of spatial use and the weakening of use-control systems. As AI becomes deeply involved in urban operation, production and consumption spaces are being reorganized. Commercial space, public space, public-service facilities, and transport systems increasingly rely on real-time data for dynamic adjustment. Public spaces, for example, can be flexibly configured according to demand; commercial facilities can adjust business content according to pedestrian flows; and transport systems can optimize flows through algorithms.

As a result, urban space is becoming more flexible and responsive. The same space can carry different functions at different times, and modes of use become highly variable. Yet current planning systems still center on static use control, predefining space through land-use categories, indicators, and standards. Built on the premise of relatively stable functions, this system struggles to adapt to highly dynamic and composite spatial use. In practice, this mismatch is already emerging: new business forms are difficult to incorporate into existing classification systems, creating approval gray zones; strict control can also constrain urban renewal, building adaptation, and spatial reuse, reducing flexibility and suppressing innovation.

The core planning issue is therefore a shift from static control to dynamic governance. One-size-fits-all control should be reduced, and more flexible use classifications should be introduced to create institutional space for temporary and composite uses. At the same time, digital means should be used for real-time monitoring and dynamic adjustment, improving spatial adaptability while safeguarding safety and public interest.

Overall, AI cities are reshaping the generative logic and operating mechanisms of urban space. At the macro level, central systems are becoming more dynamic and unstable; at the meso level, the boundaries of functional zoning are blurring and space is moving toward composite and distributed forms; at the micro level, spatial use is becoming increasingly flexible and traditional use-control systems face failure. In the face of these changes, planning needs not only new technological tools but also deeper institutional adjustment. In this sense, the AI city is not only a technological issue, but also the starting point for a transformation of the planning paradigm.

Note: The order of contributors is not hierarchical. Some content has been slightly abridged due to length limitations.

Revised: May 2026
AI-assisted translation