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（新）城市科学：利用新数据、新方法和新技术研究“新”城市

(NEW) URBAN SCIENCE: STUDYING “NEW” CITIES WITH NEW DATA, METHODS, AND TECHNOLOGIES

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摘要

以互联网产业化和工业智能化为标志、以技术融合为主要特征的第四次工业革命正以一系列颠覆性技术深刻地影响和改变着我们的城市：人们的思维方式从传统的机械思维向大数据思维转换，认知方式也逐渐向虚实结合的体验过渡，而我们赖以生存的城市，其资源利用、社会状况和空间利用也正经历着一系列变革。随着以计算机技术和多源城市数据为代表的新技术和新数据的迅猛发展，（新）城市科学在过去的十几年间逐渐兴起，成为一门融合了城市计算、人工智能、增强现实、人机交互等方向的交叉学科，为城市研究和城市规划设计带来了变革可能。目前全球范围内已涌现了多家聚焦于该领域的研究机构和多个研究项目。同时，世界各大院校也先后设置与（新）城市科学相关的学位、开设相关课程，培养更加符合新时代需求的新城市研究人才。

关键词

新城市科学；第四次工业革命；城市空间的重构与转型；大数据；颠覆性技术

ABSTRACT

The Fourth Industrial Revolution is profoundly changing our cities with a series of disruptive technologies, characterized for the boom of Internet industries and the everyday application and wide integration of intelligent technologies. Individuals' traditional mechanical thinking has changed into a mindset based on big data, whose cognition also relies more and more on a combination of both virtual and physical reality experience. At the same time, cities, where we live, are witnessing a significant revolution in resource utilization, societal conditions, and spatial use. Along with the surge of new technologies and new data represented by computer technologies and multi-source urban data, the (new) Urban Science, as a transdisciplinary combination of urban computing, Artificial Intelligence, augmented reality, and human-computer interaction, rises over the past decade. Research institutions and programs on the (new) Urban Science are flourishing globally, and increasing related degree programs and courses are offered by colleges and universities worldwide to respond to the needs of this new era.

KEY WORDS

New Urban Science; The Fourth Industrial Revolution; Urban Space Restructuring and Transition; Big Data; Disruptive Technology

1 催生新城市科学的背景

科技成果的日新月异使人们的生活方式发生了巨变，同时也影响了城市运行的各个层面。鉴于城市正在发生的种种变化，传统的城市规划设计理论与工具已无法应对新时代背景下的城市问题。然而，技术革新同时也为城市研究与实践带来了机遇——不仅促进了城市规划技术和工具的突破与创新，更在信息通讯技术快速发展的环境下，带动了数据存储、挖掘和可视化等技术的完善，赋予了人们审视城市环境的新视角[1]。

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大数据时代的城市规划可以分为两个层次：第一个层次是通过广泛获取并充分分析城市数据，使人们对所生活的城市拥有更为全面的认知；第二个层次更为深入，也更为重要，即除了对数据本身的研究和利用之外，我们更应该认识到数据产生的背后，实质上往往反映了城市生活方式与空间运行方式的变化，而多数大数据可被视为这些变化的副产品。现在各种常见的大数据（如手机信令、网络地图、线上点评等）都是生活方式演变的体现[2]。在利用数据进行城市规划设计与城市研究之前，我们应先认识到城市本身正在发生的变化及其未来演进的可能趋势。

如今，以互联网产业化和工业智能化为标志、以技术融合为主要特征的第四次工业革命正以一系列颠覆性技术深刻地影响和改变着我们的城市，这些技术包括（但不限于）人工智能（AI）、大数据与云计算、机器人、3D打印、传感网、物联网、增强现实、清洁能源、量子信息技术以及生物技术等。全球各个国家针对各自国情，分别对第四次工业革命做出了不同的战略部署：2012年，美国通用电气公司提出了“工业互联网”的概念，随后美国5家互联网行业龙头企业联手组建了工业互联网联盟；2013年，德国联邦政府教育与研究部在《德国2020高技术战略》的基础上提出了“工业4.0”战略计划；中国政府于2015年提出了“中国制造2025”行动纲领；日本于2016年提出了“社会5.0”计划；同年4月，美国颁布了《2016–2045年新兴科技趋势报告》。这场轰轰烈烈的工业革命不仅使人们的思维方式从传统的机械思维向大数据思维转换，同时也使我们的认知方式向虚实结合的体验过渡。

1 Background of the Rise of New Urban Science

Rapid scientific progresses and technological advancements have profoundly changed human lifestyles and influenced cities' operation and function at every level. Traditional theoretical explorations and tools in urban planning and design fail to respond to the emerging urban challenges. Nonetheless, technological advances bring new opportunities for urban research and practices, not only facilitating innovations in urban planning methods and tools but also contributing to the technological development of data storage, mining, and visualization, providing new perspectives to examine urban environments[1].

Urban planning in the era of big data has twofold missions: one is to improve people's understanding about cities by widely collecting and reading urban data; the other is, more importantly, to learn about the changes in urban lifestyles and spatial function patterns that urban data reveals — in this sense, most big data is a byproduct of these changes. Big data, such as mobile signaling, web maps, and online comments, is all evidencing the changes of lifestyle[2]. Learning about the ongoing changes of cities and their possibilities would be necessary for data-based urban planning and design practice, as well as urban research.

The Fourth Industrial Revolution is profoundly changing our cities with a series of disruptive technologies, characterized for the boom of Internet industries and the everyday application and wide integration of intelligent technologies. Such technologies include but are not limited to Artificial Intelligence (AI), big data and cloud computing, robots, 3D printing, sensor network, Internet of Things (IoT), augmented reality, clean energies, quantum information technologies, and biotechnologies. Nations across the globe are developing various strategies to embrace the Fourth Industrial Evolution. In 2012, General Electric Company in the U.S. proposed the idea of Industrial Internet; Later, five American Internet giants jointly established the Industrial Internet Consortium. In 2013, the Federal Ministry of Education and Research of Germany launched the strategic Industry 4.0 Program based on the High-Tech Strategy 2020 for Germany. In 2015, China came up with the “Made in China 2025” Initiative. In 2016, the Japanese government launched the Society 5.0 Program. In April of the same year, the U.S. published the report Emerging Science and Technology Trends: 2016-2045. This ongoing industrial revolution is changing individuals' traditional mechanical thinking to a new mindset based on big data, whose cognition also relies more and more on a combination of virtual and physical reality experience.

2 城市变化的驱动力

接受并准确认知第四次工业革命影响下的城市变化（即所谓“新”城市），是从事城市科学与城市规划设计相关领域工作的基本要求。本文以“新”城市变化的驱动力为切入点，着重从城市内产品/服务的变化趋势以及城市空间的重构与转型两个方面讨论城市内部正在经历的变化（图1）。

2.1 双重驱动力

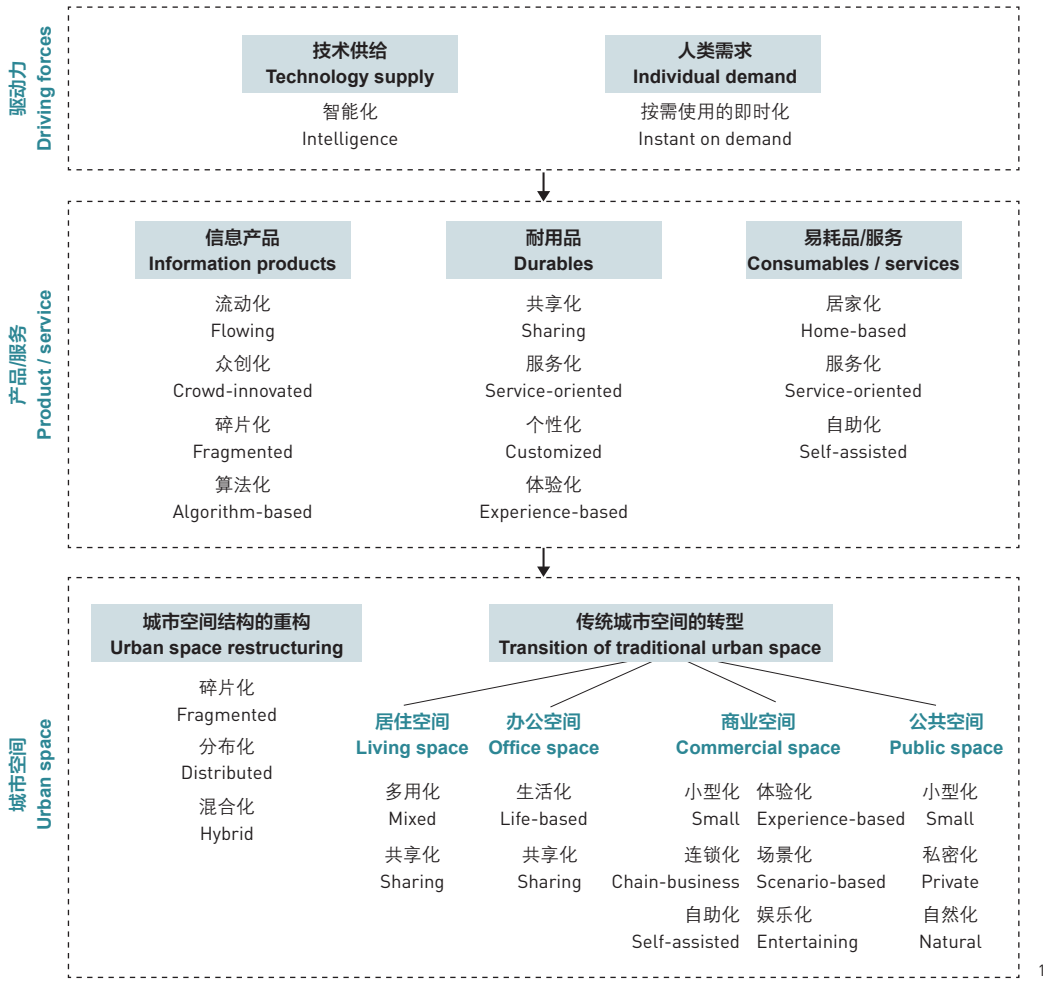
首先，AI作为技术供给，正在成为一个真正具有颠覆性意义的时代先驱，改变着我们生活中的方方面面。凯文·凯利在其著作《必然》中提到：

2 Driving Forces of Urban Changes

Professionals who engage in fields of Urban Science and urban planning and design are required to accept and update their knowledge about the urban changes brought by the Fourth Industrial Revolution (i.e. the “new” cities). By reviewing the driving forces of “new” cities, this paper focuses on the ongoing changes of cities’ products / services and the restructuration and transition of urban spaces (Fig. 1).

2.1 Two Driving Forces

First, AI, as a technical support, is disruptively defining this age and human beings’ life. In his book *The Inevitable*, Kevin Kelly points out 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….”[3]



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1. 城市变化的驱动力与变化中的城市

1. Urban changes and the related driving forces

“很难想象有什么事物会像廉价、强大、无处不在的AI那样拥有改变一切的力量……AI思想的到来加速了其他所有颠覆性趋势的进程，它在未来世界中的威力与曾经的‘铀元素’相当……当我们开始发明新的智能种类、采取新的思考方式时，将获得更大的回报……”[3]

随着科技的不断发展，“智能化”概念逐渐扩展至城市生活的各个层面，无人商店、智能住宅、智慧社区等产品相继出现，极大地提升了人类的生活和工作效率以及休闲空间的多样性及可达性。然而，智能化在为人们带来便利的同时也发出了挑战：由于智能化产品能够高效处理繁杂的机械性工作，目前许多技术含量较低、高危险或重复性高的工作正在被智能化设备所代劳，机器人等技术也开始应用于各行各业，并掀起了劳动力市场变革。[4]

然而，英国城市规划及地理学家迈克尔·巴蒂认为，AI并不能完全替代人类，二者将会在日常活动与非日常活动、短期活动与长期活动中实现分工。AI擅长从事日常活动，但不擅长处理涉及多变量或不确定性的问题。例如，AI难以取代人类制定城市长期发展规划。同时，AI擅长从事短期活动，可拓展人类对日益实时高速运转的城市的感知和理解，但难以判断和支持中长期决策和方案设计。[5]

城市变化的另一个重要驱动力是人类实时化的按需定制。凯利曾指出：“人们对于即时使用的欲望是难以满足的，即时性需要精确匹配与深层合作；人们的生活正在加速，唯一足够快的速度就是‘立即’，而信息通讯技术倾向于将每一个事物都导向按需即时使用；按需使用的即时化更偏向使用权，而非所有权；同时，人们所预期的事物处理方式也在由批处理模式向实时模式转变。”[3]

2.2 城市内产品和服务的变化趋势

2.2.1 信息产品的流动化、众创化、碎片化和算法化

信息流动化是指信息可以从一种媒介流向另一种，无论是内容还是形式都不再是固定的，而是一直处于变化和流动当中。这一现象既代表过去二三十年的主要发展轨迹，也将在未来几十年间继续存在。信息产品的流动通常会经历4个阶段：“固定、稀少”、“传播、遍在”、“流动、分享”和“开放、变化”，而其相对应的形式则会从“实体信息产品”“大量廉价的信息流”“各种信息流服务”逐步演

Since science and technology keep advancing, the concept of smartness or intelligence has been seen in every facet of urban life; self-service stores, smart housing and communities, and other intelligent-technology-supported emerging products have greatly improved humans' living convenience, working efficiency, and the diversity and accessibility of recreational spaces. However, these intelligent technologies are challenging human beings unprecedentedly: now intelligent products like robots are replacing human labor in low-tech, hazardous, or repetitive jobs and radically changing the climate of labor market in all industrial sectors.[4]

However, British urban planner and geographer Michael Batty 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.”[5]

Also, cities are changing to provide on-demand services for people's real-time needs. Kelly argues 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.”[3]

2.2 Changes of Products and Services in Cities

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

In the past two or three decades, the age of information mobility, information spread among media has no longer replied on certain forms but kept changing all the time. This will continue in the coming decades. Information products often show four phases of mobility: fixed and rare physical products; massive and cheap flows that is spread; various sharing information flow services; and crowd-innovated flows that is open and always in change. Nowadays, sweeping information-

变为“大众创造的信息流”；最终，强大的信息流服务降低了创造信息的成本，大众也能创造出新的信息流，并通过网络传播。

信息在流动过程中还会呈现出碎片化的特点。碎片化的信息虽然与现代人快速的生活节奏相适应，但也可能导致人们的学习深度不足。不难发现，与日益丰富且庞杂的信息接踵而来的是人们破碎的时间、缩短的注意力，以及肤浅的思考。同时，由于大众创造信息的成本越来越低，众创、众包的信息衍生出了巨大的商业价值，音乐、电影、书籍等艺术形式正在逐步民主化[6]。

目前，基于互联网的线上平台提供了各类实时、便捷的资讯，例如交通实况、购物消费、旅游景点等信息，人们开始习惯、甚至过分仰赖经由平台演算过的信息，这不仅导致了生活中随机效应的降低，也减少了个性化选择的可能性，渐渐形塑出一个由大量算法而非人们个性偏好驱动的城市。在高度依赖互联网信息的时代，人们的行为与选择在很大程度上被算法所左右，进而引发城市物质空间的大规模转变。

2.2.2 耐用品的共享化、服务化、个性化和体验化

近几年，“共享”概念在城市运行的各个领域蓬勃发展，共享经济重新定义了人们的生活方式。在由信息通讯技术驱动的第三方平台，人们可以更有效地重新分配或交换闲置物品或空间，甚至是个人知识经验。各种耐用品——如自行车、汽车、住房、办公室、衣橱、雨伞、充电宝、洗衣机等——都不再是简单的商品，而是以服务的形式提供给消费者。共享经济支持按需细分使用量，并强调使用权而非所有权，而服务业也即将代替制造业成为未来就业的引擎。

在当今的互联网时代，去中心化趋势日益显现，人们的生活方式也愈加多元。有别于工业时代的同质化批量生产，诸如3D打印等技术的发展大大降低了产品的制造成本，再加上社会经济水平的提升，使得供给方有足够的资源响应个性化的使用者需求，因此各式各样的定制化产品纷纷涌现。此外，在高速计算、物联网等技术的支持之下，未来城市将不止于对市民的衣食住行等基本生活需求进行供给，而是根据不同使用群体进行演算及调整，并借助技术手段实现更加高效、灵活、环保的资源分配、空间优化及市民服务。

flow services reduce the cost on information creation and enable ordinary people as agents of new information flow creation and spread.

Information mobility is also characterized for its fragmented spread, which responses today's fast lifestyle but results in a decline of people's in-depth reading, learning, and thinking in time and attention. In addition, the lowering cost of information creation shows a huge commercial potential of crowd-innovated and -sourcing information, encouraging the boom of non-elite music, films, books, and other art forms[6].

Today, people can easily get diverse instant information (such as information about real-time traffic, shopping and daily consumption, and tourist attractions) from algorithm-based online platforms. Individuals become accustomed to or even over-dependent on such information which is eliminating 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 behave as what is guided by formulated algorithms, urban physical environment would be changed dramatically.

2.2.2 Sharing, Service-Oriented, and Custom-Experience-Based Durables

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, properties, and knowledge and experience 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 services. Sharing economy makes use-on-demand work rather than use-on-ownership. It is also predicted that service industries would enjoy the greatest job market dominated now by manufacturing industries.

This age of Internet is also characterized for the 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' resource, which significantly encourages custom production. Moreover, with technological supports such as high-speed computing and IoT, cities in 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.

2.2.3 易耗品/服务的居家化、服务化和自助化

交通与信息通讯技术的发展重新定义了服务的供需关系：过去多是“人找服务”，如今则部分开始转向“服务找人”。外卖、美容、洗车、手机维修等行业的“上门服务”的涌现，使得大量原本作为服务场所的城市物质空间得到释放，并间接形成了生活—商业空间的混合使用模式，对以往的城市空间规划设计标准提出了巨大挑战。同时，还有部分传统产品和服务能够全天候自助化地向公众供给，例如自助洗车、无人便利店/书店等，使得易耗品/服务能够实现按需即时使用。

上述这些产品和服务的转变有效降低了服务供需双方的时间和出行成本，在一定程度上缓解了城市交通问题。未来，如何在城市空间的规划设计中应对这种人流、物流的转变，将是城市规划设计者、研究者和决策者不可忽视的课题。

2.3 城市空间的重构与转型

2.3.1 城市空间的碎片化、分布化和混合化

互联网时代下的新区位论是指物质空间区位正在被网络空间区位所改变甚至超越，其所导致的结果是城市结构的碎片化，城市资源布局由集中式变为分布式，城市的功能布局也由单一功能分区转化为多种功能混合。在经过重构的城市空间中，信息检索从过去基于物质空间的层级式模式向如今基于网络的扁平式模式转化。这种重构目前处于初始阶段。

2.3.2 城市空间的转型

在共享时代，许多传统的城市功能分区中的空间将得到重构或升级。近年来，众创空间、共享工作室，甚至是共享起居室正在如雨后春笋般涌现。这促进了团队与人才、创新与创业、线上与线下、孵化与投资等多方资源的整合。以万科集团为例，其于2014年率先提出“城市配套服务商”的概念，即要在10年内将技术发展与共享理念相融合，探索未来的新业务与新布局。在此目标下，万科于2017年落成了深圳“设计公社”，打造了一个集办公、居住、商业等功能于一体的租赁型创业社区，在有限的城市空间内高效地满足了人们的诸多诉求；同时，其以低廉的租金吸引了大量产业群聚，创建了一系列产业

2.2.3 Home-Based, Service-Oriented, and Self-Assisted Consumables / Services

Transportation development and advances of information and communications technology have together redefined supply-demand relations of urban services: a more precise supplier-consumer matching mode is formed. Door-to-door services, such as food delivery, hairdressing, car washing, and cellphone repair, no longer needs a physical store, which would vacate a large amount of urban space and encourage the emergence of living-commercial space in cities. All these have challenged the existing standards of urban spatial planning and construction. At the same time, quite a few of consumables and services are supplied to the public 24 / 7 in self-assisted forms, such as car washing, convenience stores, and book stores.

Changes in products and services in cities not only efficiently save time and travel costs of both suppliers and consumers, but also help relieve the traffic pressure by reshaping flows of urban population and goods. In the future, urban planners, designers, researchers, and decision-makers are expected to respond to these changes.

2.3 Urban Space Restructuring and Transition

2.3.1 Fragmented, Decentralized, and Hybrid Urban Space

The new location theory in the age of Internet proposes that physical spatial locations are changed or even disrupted by network-space locations, resulting in fragmented urban space pattern, decentralized distribution of urban resources, and hybrid of urban land-uses. In the restructured urban spaces, information hierarchy that was built on physical spaces is shifting towards a flat network-based structure. Such restructuring just begins.

2.3.2 Urban Space Transition

In the age of sharing, the traditional urban land-use mode would be restructured or upgraded. Maker space, co-working space, and even co-living space are gaining momentum over the past few years, which accelerates the integration of teams and talents, innovation and entrepreneurship, online and offline resources, incubation and investment supports, and so on. The Vanke Group firstly proposed the idea of City Supporting Service Provider in 2014 to set up new sharing business and the corresponding spatial forms by 2024 by integrating with 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. Its low rental has attracted a number of

链完整的创业社区，打破了传统的职住分离模式，实现了工作与生活空间的有机融合。此类探索在国内外大城市中正日益增多。

一方面，城市公共空间将有望从巨大的集中式公共空间裂变为大量小型公共空间[7]，服务于微型共同体。例如，巴塞罗那遍布的微型广场组成了充满活力的城市公共空间网络；另一方面，为了满足人们回归自然的需求，拥有自然景观元素的公共空间也不断涌现[7]。同时，商业空间也呈现出向小型化、连锁化、自助化、体验化、场景化和娱乐化转变的趋势。

3 （新）城市科学

3.1 （新）城市科学的提出

当今，处于急剧变化中的城市亟需与之对应的理论、研究范式及技术方法，以有效指导人们更科学地理解城市的本质和发展进程，并更准确地预测城市规划方案和发展政策对于城市发展的干预结果。（新）城市科学的提出势在必行[8]。考虑到“新城市科学”和“城市科学”在国际上均有使用，本文使用“（新）城市科学”这一名词对其进行引介。

（新）城市科学与复杂科学有着密不可分的关系。20世纪80年代以来，在自然科学及社会科学中一直盛行的复杂运动泛指利用复杂、非线性及非均衡系统相对于简单、线性及均衡系统所进行的观念革新[9]。与（新）城市科学相关的复杂科学学派包括：以美国圣塔菲研究所为代表的复杂科学学派，以美国城市及区域规划专家路易斯·霍普金斯为首的伊利诺规划学派，以及以迈克尔·巴蒂为代表的城市科学学派[9]。霍普金斯将城市系统的复杂性归纳为相关性、不可分割性、不可逆性和不完全预见性，并据此提出了制定城市发展计划的逻辑[10]。而巴蒂则指出：城市是一个以自下而上发展为主的复杂系统，其规模和形态遵循

business groups to settle down, and many full-industrial-chain entrepreneurial neighborhoods of various sectors are 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-scaled urban public spaces would be transformed into massive smaller ones[7] so as to serve micro communities. Barcelona, for example, is a city where micro squares are ubiquitous and form a vigorous network of urban public spaces. Also, the number of public spaces with natural landscapes is increasing to meet people's desires of returning to nature[7]. Moreover, the commercial space is shrinking in size to serve chain-business for self-assisted, scenario-experience-based, and entertaining services.

3 (New) Urban Science

3.1 The Birth of (New) Urban Science

New theories, research paradigms, and technologies are widely needed to deal with ongoing drastic changes in cities to help individuals better understand the essence and development of cities and more accurately predict implementation results of urban planning schemes and urban development policies. A new Urban Science is required[8]. In light of the fact that both the terms “New Urban Science” and “Urban Science” are now used internationally, this paper uses “(new) Urban Science” for a general discussion.

(New) Urban Science is closely related to Complexity Science. The Complexity Movement that has been widely seen in both natural and social sciences since the 1980s, refers to a philosophical reform from adopting simple, linear, and balanced systems towards embracing complex, non-linear, and imbalanced systems in research and practice[9]. Complexity Science schools related to (new) Urban Science include the Complexity Science school represented by the American Santa Fe Institute; the Illinois School of Planning represented by the American urban and regional planning expert Lewis Hopkins; and the Science of Cities school represented by Michael Batty[9]. Hopkins measured the complexity of urban systems through lenses of interdependence, indivisibility, irreversibility, and imperfect foresight, and proposed a methodology to develop urban planning schemes[10]. Batty argued that “cities are complex systems that mainly grow from the bottom up, and their size and shape follow well-defined scaling laws that result from intense competition for space. To understand space of cities, we must understand how flows and networks compose the system of the city.”[5] Based on Complexity Science, Batty proposed the

① 以下机构及项目的简介部分来自于其官方网站。

① Part of the introduction of the listed research institutions or programs are cited from their official websites.

因空间争夺而导致的扩展规律；认识城市不仅仅是理解城市空间，还需要理解流动和网络如何塑造城市[5]。巴蒂在复杂科学的基础上对城市科学中的区域科学及城市经济学内涵加以系统整理，称之为“新城市科学”（New Science of Cities）[5]。

新加坡苏黎世联邦理工学院中心未来城市实验室的前负责人彼得·爱德华于2016年提出“新城市科学的目标是使城市更加可持续、更具韧性、更加宜居”[11]。美国学者安东尼·汤森德认为，新城市科学应该具备三个基本特征：两种传统研究方法的对抗（即探索城市个性化的描述性研究方法与揭示影响城市结构和动态的共同过程的演绎研究方法）、多学科理论方法的支撑，以及数字技术的研究与应用[8]。

随着以计算机技术和多源城市数据为代表的新技术和新数据的迅猛发展，（新）城市科学以深入量化分析与数据计算途径等研究模式为依托，在过去的十几年间逐渐兴起。传统的城市科学更多地体现为基于静态的、截面的和系统论视角的“区域科学”。致力于解读和认识“新”城市的（新）城市科学，运用的则是过去20~25年内发展出来的新技术、新工具和新方法，其具有演进性和复杂科学特性，以及更强烈的离散性和自下而上的学科思想。

3.2 （新）城市科学的发展现状

在全球高速的非可持续城市化进程给环境带来的巨大冲击与挑战面前，人们对（新）城市科学的关注达到了前所未有的高度。不同于20世纪60年代庞大而复杂的城市模型研究，当前的（新）城市科学不仅具有远胜于彼时的运算能力和海量数据支持，还更关注技术与数据支持下的使用体验。以城市计算、增强现实、人机交互等方向为代表的多学科交叉的（新）城市科学正在为城市规划设计带来新的变革可能。

3.2.1 相关研究机构/项目

目前，全球范围内已涌现多家聚焦于（新）城市科学的研究机构，并引起了欧美众多知名院校的高度重视。笔者在前人研究[8]的基础上对这些研究机构进行了补充①，主要包括：

（1）麻省理工学院媒体实验室城市科学工作组

成立于1986年的麻省理工学院媒体实验室是一个致力于融合科技、媒体、科学、艺术和设计的跨学科研究室。其城市科学工作组以职住地研究、城市建模/模拟和预测，以及移动性需求研究为主。同时，他们与多家国际科研院校及机构——同济大学（中国上海）、台

concept of New Science of Cities by sorting out the content and knowledge about Regional Science and Urban Economy in the disciplinary framework of Urban Science[5].

In 2016, Peter Edwards, former director of the Future Cities Laboratory of Singapore-ETH Center, proposed that “the new urban science aims to make cities more sustainable, resilient, and livable.”[11] The American scholar Anthony Townsend identified three characteristics of the new urban science. First, it involves a confrontation of two traditionally separate modes of inquiry — the descriptive approach to understand the individuality of cities, and the deductive scientific approach to uncover the common processes that influence the structure and dynamics of all cities; secondly, it is multidisciplinary and draws upon theoretical ideas across the contributing disciplines; thirdly, it depends upon the access and application of digital technologies[8].

Along with the boom of new technologies (such as computer technologies) and new data (such as multi-source urban data), the (new) Urban Science based on in-depth quantitative analysis and data computing rises over the past decade. If we regard the traditional Urban Science as a kind of regional science that emphasizes static, cross-sectional, and systematic studies, the (new) Urban Science then is an evolving and complicated science developed to examine and interpret “new” cities by employing new technologies, tools, and methods emerging in the past 20 to 25 years. The discipline shows a stronger dispersion and a bottom-up ideology.

3.2 Current Achievements of (New) Urban Science

(New) Urban Science is a response to the unprecedented environmental challenges brought by the rapid and unsustainable global urbanization. Unlike studies on the massive and complex urban models in the 1960s, the (new) Urban Science, supported with powerful computing technologies and massive data, focuses more on users’ experience. With a multi-disciplinary framework of urban computing, augmented reality, human-computer interaction, and so on, the (new) Urban Science is bringing new possibilities for urban planning and design.

3.2.1 Research Institutions / Programs on (New) Urban Science

The (new) Urban Science now is studied and promoted by a number of research institutions globally, including several renowned international colleges and universities. By supplementing previous studies[8], this paper lists a few of them①.

(1) City Science, MIT Media Lab

Founded in 1986, the MIT Media Lab is dedicated to trans-disciplinary research topics, covering technology, media, science, art, and design. Its group research is organized around

北理工大学（中国台北）、港口城市大学（德国汉堡）、阿尔托大学（芬兰赫尔辛基）、安道尔大学（安道尔）和瑞尔森大学（加拿大多伦多）——展开合作，建立“城市科学网络计划”，将其研究拓展到全球领域。该工作组致力于城市发展的概念研究和关键技术开发，以支持其在全球范围内的合作者根据各自的独特背景对这些概念和技术进行拓展、应用和评估。他们还计划在拉丁美洲、非洲和印度等地区欠发达但发展迅速的城市中开展各类新项目，因为在这些城市中，新提出的城市化应对策略对其城市化进程的影响可能会更加显著。

（2）麻省理工学院感知城市实验室

成立于2004年的麻省理工学院感知城市实验室旨在从多学科视角描述和解读城市建成环境中的新变化，并通过设计途径及开发相关城市研究工具更好地了解城市，同时也让城市更好地感知到我们自己。

（3）新加坡苏黎世联邦理工学院中心未来城市实验室

该实验室由瑞士苏黎世联邦理工学院与新加坡国家研究基金会于2010年联合创立，旨在通过科学方法与在地化设计途径，创建可持续的未来城市。其研究领域包括建筑与数字建造、城市设计策略与资源、城市社会学、景观生态、移动及交通规划、模拟平台和人居环境等。

（4）新南威尔士大学建成环境学院城市分析实验室

新南威尔士大学建成环境学院城市分析实验室成立于2018年，以支持协作城市规划和开展以用户为中心的设计为目标。该实验室配备有大型决策支持演绎室、三个VR/AR室、可感知沙盒平台和实验观察室，旨在营建可持续、高效、宜居且具有韧性的未来城市，并为研究与城市规划和设计相关的决策过程提供机会。

（5）哈佛大学肯尼迪政府学院艾什中心“数据智能城市对策”计划

该计划聚焦于政府事务与数据的交叉领域，通过开放数据、预测性分析和公众参与技术等途径，旨在推动涉及新兴数据的地方政府

three themes: places for living / working; urban modeling, simulation, and prediction; and mobility on demand. MIT City Science has developed cooperative City Science Labs at Tongji University (Shanghai, China), Taipei University of Technology (Taipei, China), Hafencity University (Hamburg, Germany), Aalto University (Helsinki, Finland), Andorra University (Andorra), and Ryerson University (Toronto, Canada) for its international City Science Network research. It also develops concepts and key technologies that can be extended, employed, and evaluated by their collaborators in unique contexts around the globe. City Science group is going to develop new projects in less affluent but rapidly growing cities in Latin America, Africa, and India where the impact of a new process to address the challenges of urbanization may be the greatest.

(2) SENSEable City Laboratory, MIT

Founded in 2004, the SENSEable City Laboratory of MIT aims to describe and understand the emerging built environment through a multidisciplinary approach, to predict and examine the new changes, and deploy tools to learn about cities — so that cities can learn about us.

(3) Future Cities Laboratory, Singapore-ETH Center

This laboratory was jointly founded by ETH Zurich and Singapore’s National Research Foundation in 2010. The lab is structured to link science, design, and specific places to create urban sustainability by combing research in architecture and digital engineering, urban design strategy and resource, urban sociology, landscape and ecosystem, mobility and transportation planning, simulation platform, and living environment.

(4) City Analytics Lab, Faculty of Built Environment, University of New South Wales

The City Analytics Lab, Faculty of Built Environment, University of New South Wales was founded in 2018 to support collaborative urban planning and user-centered design. The lab compromises a large decision support theatre, three VR / AR rooms, along with a Tangible Table sandbox and observation rooms, supporting the envisioning of sustainable, efficient, liveable, and resilient future cities and providing an opportunity to study the decision-making process associated with urban planning and design.

(5) Data-Smart City Solutions, Ash Center, Harvard Kennedy School

Focusing on the crossing sector of government affairs and data, this program focuses on the intersection of government and data, ranging from open data and predictive analytics to civic engagement technology, serving as a resource for

项目，并为相关城市提供资源平台。其着重于推广前沿的实践、创新者和案例研究（包括分析和可视化有关人类健康和服务、基础设施、公共安全等方面的数据，以提供城市规划优化措施），并加强前沿行业、学界和政府官员之间的沟通与交流，力求促进跨机构数据与社区数据的结合，从而更及时有效地发现并解决公共问题。

（6）芝加哥大学城市计算与数据中心

建立于2012年的芝加哥大学城市计算与数据中心将美国阿贡国家实验室在物理和工程科学方面的优势与芝加哥大学在社会科学、经济学和政策方面的专业知识相结合，开发计算研究工具并积极促进研究者、政府机构、建筑公司、私营企业和公民志愿者的联合协作，共同理解并改善城市。

（7）纽约大学城市科学与发展中心

纽约大学城市科学与发展中心建立于2012年，其将纽约市作为研究场所和研究对象，关注城市信息化领域，研究主题涵盖数据科学、城市运转、市民科学、数据可视化、建成环境、可持续性等方面。

（8）哥伦比亚大学空间研究中心

哥伦比亚大学空间研究中心成立于2015年，是一个将设计、建筑、城市规划等学科与人文科学和数据科学相联系，并提供空间专业知识的城市研究中心。其为围绕数据可视化、数据收集和数据分析等新技术开展的研究和教学活动提供支持，关注数据认知和大数据，致力于研发先进的设计工具，帮助学生、学者、合作者和使用者了解全球城市的过去、现在和将来。

（9）伦敦大学学院巴特莱特高级空间分析中心

伦敦大学学院巴特莱特高级空间分析中心建立于1995年，研究焦点为空间分析技术和仿真模型在城市和地区尺度的应用和可视化。该中心与伦敦市政府及多家研究机构开展合作，运用新城市科学对各类

cities interested in catalyzing adoption of data projects on the local government level. By highlighting best practices, top innovators, and promising case studies (in research and visualization of data in human health and service, infrastructure, public security, etc. to improve urban planning schemes) while connecting leading industries, academia, and government officials, and promoting the combination of integrated, cross-agency data with community data to preemptively discover and address civic problems.

(6) Urban Center for Computation and Data, University of Chicago

As a jointly founded research institute between the University of Chicago (UOC) and Argonne National Laboratory (ANL) of the U.S. in 2012, the Urban Center for Computation and Data leverages ANL's advantages in Physics and Engineering Sciences with UOC's strength in social sciences, Economics, and policies, to develop tools for computation study, encourage collaborations among researchers, governments, construction companies, private enterprises, and volunteers to reinterpret and improve cities.

(7) Center for Urban Science and Progress, New York University

Founded in 2012, the Center for Urban Science and Progress, New York University uses New York Cities as both laboratory and classroom. It focuses on Urban Science and Informatics, covering topics from data science, city operation, civic science, data visualization, built environment, and sustainability.

(8) Center for Spatial Research, Columbia University

Founded in 2015, the Center for Spatial Research of Columbia University connects disciplines such as Design, Architecture, and Urban Planning with Social and Data Sciences to support research and teaching activities on new technologies such as data visualization, collecting, and analysis with a special focus on data perception and big data. This center develops tools for students, faculty, and practitioners engaging in spatial research to review the history, examine current developments, and predict future possibilities.

(9) The Bartlett Center for Advanced Spatial Analysis, University College London

The Bartlett Center for Advanced Spatial Analysis, University College London was built in 1995. It focuses on the application and visualization of spatial analysis technologies and authentic model study at city and regional scales. The center works with the municipal government and a number of research institutions to simulate and visualize urban issues with methods associated with the (new) Urban Science. Its

城市问题进行模拟和可视化。其研究领域包括城市交通与人口、气候变化、物联网设施布局等。

（10）昆士兰科技大学设计实验室城市信息中心

成立于2006年的昆士兰科技大学设计实验室城市信息中心，通过整合人文科学和社会科学、设计、规划和建筑、人机交互、信息技术和计算机科学等学科，关注不同建成环境下的城市体验的研究、设计和实践。

其他国际（新）城市科学相关研究机构还包括：创立于1996年的亚洲计算机辅助建筑设计研究协会；日本东京大学于1998年成立的空间信息科学中心；创立于2004年的卡洛·拉蒂设计工作室；2012年由伦敦大学学院、帝国理工学院及英特尔公司共同创建的英特尔可持续联结城市联合研究中心；2014年由荷兰代尔夫特理工大学、瓦格宁根大学与麻省理工学院联合创建的阿姆斯特丹高级大都市研究中心；2014年由英国经济与社会研究委员会资助成立的格拉斯哥大学城市大数据中心；于2014年建立的美国卡内基梅隆大学21世纪大都市智能城市研究中心；以及斯坦福大学于2016年成立的空间研究中心。其他国际（新）城市科学相关研究项目还包括美国圣塔菲研究所于2005年启动的“城市、规模与可持续性研究项目”，2011年由哈佛大学、美国东北大学及波士顿市政府联合发起的“波士顿区域研究计划”，以及于2013年启动的爱尔兰梅努斯国立大学“可编程城市项目”等。

中国（新）城市科学相关研究机构或项目包括：成立于1993年的清华同衡数字城市研究所开展的智慧城市规划与研究专项设计；成立于2012年、由中国城市科学规划设计研究院与中国城市科学研究会联合建立的数字城市工程研究中心和智慧城市联合实验室；于2013年成立的北京城市实验室开设的诸多基于新数据、新方法和新技术的城市空间认知和数据增强设计研究；成立于2019年的中国城市科学研究会城市数据安全管理中心等。

research scope covers urban traffic and population, climate change, IoT facility arrangement, etc.

(10) Urban Informatics Group, Queensland University of Technology Design Lab

Founded in 2006, the Urban Informatics Group, Queensland University of Technology Design Lab focuses on the research, design, and practice related to urban experience in different built environments, by integrating disciplines such as Humanities and Social Sciences, Design, Planning and Architecture, Human-Computer Interaction, Information Technologies, and Computer Science.

Other international research institutions in the field of (new) Urban Science include the Association for Computer-Aided Architectural Design Research in Asia founded in 1996; the Center for Spatial Information Science founded in 1998 by Tokyo University; the Carlo Ratti Associati established in 2004; the Intel Collaborative Research Institute for Sustainable Connected Cities jointly built by University College of London, Imperial College London, and Intel in 2012; the Amsterdam Institute for Advanced Metropolitan Solutions jointly built by Delft University of Technology, Wageningen University, and MIT in 2014; the Urban Big Data Center of the University of Glasgow funded by the Economic and Social Research Council of UK in 2014; the Metro21: Smart Cities Institute established by Carnegie Mellon University in 2014; and the Center for Spatial Research of the Stanford University founded in 2016. Some other international programs related to the (new) Urban Science include the Cities, Scaling, and Sustainability Research Project launched by the Santa Fe Institute in 2005, the Boston Area Research Initiative jointly launched by Harvard University, Northeast University of the U.S., and the government of Boston, and Programmable City Project, Social Sciences Institute, National University of Ireland Maynooth launched in 2013.

China’s research institutions and programs in (new) Urban Science include the Smart City Planning and Research Project initiated by Tsinghua institute of Urban Planning and Design of Digital City founded in 1993; the Digital City Engineering Research Center and the Smart City Joint Lab co-founded by Chinese Institute of Urban Scientific Planning and Design and the Chinese Society for Urban Studies in 2012; the research programs on urban space cognition and data augmented design with new data, methods, and technologies launched by Beijing City Lab founded in 2013; and Administration Center of Urban Data Safety established by the Chinese Society for Urban Studies which was founded in 2019.

表1：国内外新城市科学相关学位与科研院系
Table 1: Degrees and research institutions on the (new) Urban Science in Chinese and foreign universities

	院校 Universities	院系 Schools / departments	学位/科系 Degrees / disciplines
学位 Degrees	麻省理工学院 Massachusetts Institute of Technology (MIT)	城市研究与规划系 电子工程与计算机科学系 Department of Urban Studies and Planning Department of Electrical Engineering and Computer Science	城市科学/规划与计算机科学联合学士学位 Bachelor of Science in Urban Science and Planning with Computer Science
	纽约大学 New York University	纽约大学城市科学与发展中心 Center for Urban Science and Progress	应用城市科学与信息化硕士学位 Master in Applied Urban Science and Informatics
	美国东北大学 Northeastern University	公共政策与城市事务学院 School of Public Policy and Urban Affairs	城市信息化硕士学位 Master in Urban Informatics
	西班牙马德里理工大学 The Technical University of Madrid	工程与建筑学院 Schools of Engineering and Architecture	城市科学硕士学位 Master in City Sciences
	澳大利亚新南威尔士大学 University of New South Wales	建成环境学院 Faculty of Built Environment	城市分析硕士学位 Master of City Analytics
	伦敦大学学院 University College London	伦敦大学学院巴特莱特高级空间分析中心 The Bartlett Centre for Advanced Spatial Analysis	智慧城市与城市分析硕士学位 Master in Smart Cities and Urban Analytics
科研院系 Institutions	宁波大学 Ningbo University	建筑工程与环境学院 Faculty of Architectural, Civil Engineering and Environment	城市科学系 Urban Science
	上海师范大学 Shanghai Normal University	环境与地理科学学院 School of Environmental and Geographical Sciences	城市科学与区域规划系 Urban Science and Regional Planning
	北京联合大学 Beijing Union University	应用文理学院 College of Arts and Science	城市科学系 Urban Science

3.2.2 学术期刊

在（新）城市科学领域，期刊名称中明确包含“Urban Science”的学术期刊共两本，即已有20余年历史的《城市科学国际期刊》（ISSN：1226–5934）和新晋的《城市科学》期刊（ISSN：2413–8851），后者由加州理工大学戴维斯分校的迈克尔·彼得·史密斯教授于2016年创办、2017年3月首次发行。

3.2.3 相关学科与课程

近年来，国内外院校纷纷设立与（新）城市科学相关的学科及学位（表1）。其中，2018年5月16日，麻省理工学院批准设立城市科学/规划与计算机科学联合学士学位[12]，获得全球学者与相关从业者的高度关注。在传感网、大数据、量化分析、交互式通信和社交网络、分布式智能、无人驾驶、重点基础设施物联网、生物识别、

3.2.2 Academic Journals

In academia related to (new) Urban Science, there are two journals whose names include “Urban Science”: one is *International Journal of Urban Sciences* (ISSN: 1226-5934) with a history of over 20 years; the other is *Urban Science* (ISSN: 2413-8851), which was founded by Michael Peter Smith, professor at the University of California at Davis in 2016, with its first issue published in March 2017.

3.2.3 Disciplines and Courses on (New) Urban Science

Chinese and foreign colleges and universities have started to set up disciplines and degree programs on (new) Urban Science in recent years (Table 1). The bachelor degree of Science in Urban Science and Planning with Computer Science[12] was introduced in MIT on May 16, 2018, receiving wide attention from academic and practitioner circles. In face of the profound changes in cities brought about by technological advances

共享经济等一系列技术革新给城市带来深刻变革这一大背景下，此学位的设立旨在通过整合城市规划和公共政策、设计和可视化、数据分析、机器学习、传感网技术、机器人技术、新材料，以及其他计算机科学和城市规划领域的相关内容，以一种前所未有的方式理解城市和城市数据，并重塑现实世界。

然而，中国院校目前尚缺乏与（新）城市科学相关的课程。值得一提的是，2018年秋，清华大学建筑学院开设了“新城市科学”本科生课程，成为中国首个开设（新）城市科学相关课程的城乡规划专业院系，引发了学界的广泛关注。

清华大学开设的“新城市科学”课程旨在让学生在了解当前各专业领域的前沿技术与方法的基础上，客观认识和理解城市系统及其发展规律，从而对城市研究、规划与管理的重要理论与方法支撑形成比较全面的掌握。该课程结合了中国城市发展的规律和前沿技术发展的特点，秉承城市认知与技术方法并重的原则，内容涵盖物理和人体传感器、虚拟现实与增强现实、智能建造、计算机视觉、高级应用城市模型、智慧城市等方面，旨在挖掘新数据、新方法和新技术在城市领域的应用，拓展学生对（新）城市科学前沿技术的认知视野，丰富相关知识结构。

受到（新）城市科学当下所呈现的跨行业数据交流和跨领域技术合作等显著特征的影响，该课程以跨学科讲授为主（如邀请来自不同学科和行业的专家加入授课教师队伍），辅以课堂教学和校外参观相结合的形式，向全校不同学科背景的学生授课（所有专业的本科学生都可以选修）。课程从新技术、新数据、新领域三个维度出发，邀请了来自城市规划、计算机、大型互联网企业等领域的知名专家学者和一线从业人员，向学生介绍近5年来世界范围内涌现的认识城市和改变城市的前沿研究与方法。经过课程教学，学生能够更深入地理解城市这一复杂系统的特征及发展规律，客观地了解中国城市研究、城市规划设计与管理领域的重要理论与方法，并能够更直观地感受城市空间相关的学科发展与行业动态之间的紧密联系。

including sensor network, big data, quantum analysis, interactive communication and social interaction network, distributed intelligence, autonomous driving, IoT on key infrastructure, biometrics, and sharing economy, this bachelor program is developed to reinterpret city and urban data by integrating urban planning and public policies, design and visualization, data analysis, machine learning, sensor network, robots, and new materials, etc. so as to reshape the physical world.

However, there are few courses on (new) Urban Science in China’s colleges or universities. The undergraduate program “New Urban Science” provided by the School of Architecture of Tsinghua University, established in fall of 2018, is the first course on the (new) Urban Science in China’s urban and rural planning education system.

This course aims to help students understand urban systems and the development laws by updating their knowledge about cutting-edge technologies and methods in different fields to better master and apply these key theories and methods to urban research, planning, and management. Based on an in-depth exploration of the development reality of Chinese cities and the advantages of different technologies, the course covers IoT and human sensors, virtual reality and augmented reality, intelligent construction, computer vision, advanced city modeling, and smart city, encourages applications of new data, methods, and technologies in cities, opens students’ horizon of latest achievements in the (new) Urban Science, and enriches their knowledge structure.

In light of the trend of multi-profession data exchanges and cross-sector technological collaborations in the (new) Urban Science, this course features transdisciplinary lecturing by inviting experts with different disciplinary backgrounds to join the faculty, in forms of indoor classes and fieldstudies. The course is open to all bachelor students in the university. The course framework is built in dimensions of new technologies, new data, and new sectors, and renowned scholars and experts in urban planning, computer science, as well as leading practitioners from Internet giants are invited to introduce important research and innovative methods related to the (new) Urban Science that emerge in the recent few years. Through this course, students are expected to improve their understanding on complex urban systems, the key theories and methods on urban study, urban planning and design, and urban management in China, as well as the dynamic interactions between the disciplinary and industrial development related to urban spatial construction.

4 结语

“我们无法去预测未来城市，但是我们可以创造它们。作为复杂系统的城市，几乎不可预测……城市是无数不遵循任何发展规划的个人决策和集体决策的产物，它们是我们发明的，它们也在不断进化……到本世纪末，绝大多数的世界人口都将居住在城市当中，这些城市或大或小，彼此连接，而在一个完全城市化的世界里，我们将会很难用物理边界再去定义城市。”[13]

经过对国内外发展动态的系统梳理，能够看出（新）城市科学正在世界各地以各种形式涌现。但需要指出的是，部分学术研究和研究机构虽然冠以“城市科学”之名，但实际上研究的还是老/旧的城市，而非深受第四次工业革命影响的“新”城市，这也是近期这一学科需要改变的现状问题之一。

巴蒂在其于2018年底出版的《创造未来城市》一书中阐释了在迎接即将到来的全球城市化的过程中，我们应当如何去定义和描述未来城市的结构、层次、扩展和更新，以及技术变化的浪潮将会如何在改造和创新城市的过程中发挥至关重要的作用[13]。无论我们是否已经准备好，未来城市和（新）城市科学都会以超越想象的速度来到我们眼前。**LAF**

4 Conclusions

“We cannot predict future cities but we can invent them. Cities are largely unpredictable because they are complex systems.... Cities are the product of countless individual and collective decisions that do not conform to any grand plan. They are the product of our inventions; they evolve…. By the end of this century, most of the world’s population will live in cities, large or small, sometimes contiguous, and always connected; in an urbanized world, it will be increasingly difficult to define a city by its physical boundaries.”[13]

This paper reviews the boom of the research agencies and programs of (new) Urban Science in a variety of topics and forms across the globe. However, many research programs or institutions named with “urban science” still focus on studying traditional cities, instead of the “new” ones influenced by the Fourth Industrial Revolution. In the near future, a shift is expected in research concepts and interests.

In his work *Inventing Future Cities* published in late 2018, Batty discusses the coming great transition from a world with few cities to a world full of cities. He describes the structure, hierarchy, spread, and renewals of future cities. He also maps the waves of technological change that grow increasingly intense and lead towards continuous innovation, as a process of creative destruction where future cities will emerge[13]. Be ready or not, ones will be engaged in future cities and the (new) Urban Science at an unexpected speed. **LAF**

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