FUTURE CITIES

NEW ECONOMY AND SHARED CITY PROSPERITY

DRIVEN BY **TECHNOLOGICAL INNOVATIONS**

Discussion Papers

UN-HABITAT FOR A BETTER URBAN FUTURE

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UN HABITAT
FOR A BETTER URBAN FUTURE

FUTURE CITIES, NEW ECONOMY, AND SHARED CITY PROSPERITY DRIVEN BY TECHNOLOGICAL INNOVATIONS

United Nations Human Settlements Programme (UN-Habitat)
P.O. Box 30030 00100 Nairobi GPO KENYA
Tel: 254-020-7623120 (Central Office)
www.unhabitat.org

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Principal authors: Michael Keith, Jian Gao, Tao Zhou, Quanhui Liu, Hui Zeng, Mingxiao Zhao, Baolin Cao, Gerhard Schmitt, Jaideep Gupte, Saiful Ridwan, Harrison Simotwo, Pietro Visetti, Keli Zhu, Hongshan Zhang, Shudong Cui, Yifan Li, He Jia, George Economides, Zhiyong Fu, Peter Scupelli, Jiajun Xu, Xinyue Wu, Haishan Wu, Lei Yin, Shantian Cheng, Deyi Wu, and Bingnan Yin
UN-Habitat Contributors: Marco Kamiya
Chief Editor: Lei Guo
Editors: Sonola Onasanya, Mingxiao Zhao, and Hui Zeng
Design and Layout: Kelvin Malombe

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Ms. Maimunah Mohd Sharif

United Nations Under-Secretary-General
and Executive Director, United Nations
Human Settlements Programme (UN-Habitat)

Whether standing on the streets of Kuala Lumpur, Nairobi, or New York, it is often challenging to imagine what these cities will look like in the coming decades. What new pathways to sustainable urban development will we create if we combined and applied a social, economic, environmental, and cultural lens to guide us towards sustainable urbanisation? To achieve a sustainable urban future, we need an integrated approach combining cutting-edge ideas and talent through a participatory process that brings out the best of our global and urban family. Technology and innovative thought need to be combined with concrete actions to ensure we are able to attain Sustainable Development Goal 11, which is to create inclusive, safe, resilient, and sustainable cities.

Today, city planners are considering new means of transportation in the re-planning of their cities. Computer scientists are analysing data to give new solutions to old problems such as gender-bias decision-making. Creative and smart local governments are applying evidence-based policies to benefit communities. Technology forces us to rethink our current urban management systems. This ultimately alters the very conception of city development, moving closer to quality of life and defined by new indicators of inclusive growth.

UN-Habitat's new Urban Knowledge and Innovation Branch aims to lead this movement for sustainable, innovative solutions. This report Future Cities, New Economy, and Shared City Prosperity Driven by Technological Innovations pulls together thought-provoking discussion papers from the leading experts in urban development, technological innovation, finance, design, and sustainability. The papers explore the themes of: how to effectively analyse new trends in city development; how to develop urban infrastructure that is smart, inclusive, and relevant to its specific context; best practices in testing and implementing new ideas on city development for long-term success; and the interdisciplinary merger of city development, economics, and finance for a more inclusive future.

I would like to thank the contributors for sharing their knowledge and expertise with us. I would like to offer special thanks to the Chengdu People's Municipal Government of China for their support and to the team at UN-Habitat who worked hard to make this publication possible.

Foreword

Mr. Justin Yifu Lin

Dean, New Structural Economics, Peking University
Former Chief Economist, World Bank

The concept “Economic Growth” proposed by the 1971 Nobel Economic Prize Laureate Simon Smith Kuznets indicates twofold meanings as follows: one is modern economic growth, while the other is pre-modern economic growth. The pre-modern economic growth lasted until the 18th century. During that period, the economic growth rate basically depended on the population growth rate, and the average income level did not significantly increase. Since the 18th century, the annual average income growth rate of developed countries such as those in western Europe had jumped to 1% from about 0.05% in the era of pre-modern economic growth, and it had even doubled up to 2% by the end of the 19th century. Such dramatic development can be attributed to successive technological revolutions, including steaming in the first industrial revolution, electrification in the second one, informatization via computer and the Internet in the third one, and intelligence based on big data, cloud computing and artificial intelligence in the emerging fourth one.

Besides effective market mechanism, new economy calls for facilitating state to provide service and solve market failures certainly happening in the process of technological innovation. For instance, given the fact that new technology relies heavily on research and development (R&D), the scale of enterprises’ investment on development would be quite huge and the risk of a development activity would be very high, while the probability of failure would be not low. Enterprises would be passive to carry out technological development without being endowed any patent licenses, which are normally issued and granted by the government. In addition, the government also needs to support basic research, the breakthrough of which is a public goods and needed for the development of new technology.

Moreover, new technology can be well deployed into practice only if adequate hard and soft infrastructure is available. The new economy is currently in demand for support of infrastructure such as cloud computing, big data, Internet of things and 5G network, while railway, road and many other types of hard infrastructure primarily aim at traditional industries in the past.

New business forms would not come into being and new technology would not be able to really improve economic efficiency without new types of infrastructure.

Soft infrastructure, or so-called institutional arrangement, is also indispensable. New technology should be generated or applied by technical and production talents, but it is difficult for entrepreneurs themselves to cultivate these human resources from a preliminary education level or without any help. It is the government that should provide higher education or even postgraduate education to cultivate these talents with anticipation for potential new technological revolution in the future.

There would be a large number of opportunities for us to apply new technology into various scenarios, which calls for constant trial, especially action by the first mover. New business forms are normally fostered not by large-scale mature firms, but by some young people who are familiar with technology, sensitive to market, open-minded and full of new ideas.

Since the reform and opening-up in the late 1970s, China has made great achievements based on early trial and pilot in some local regions, which has been a very valuable principle of policy practice. In order to well cope with novel phenomena and capture new opportunities, the government pilots policies in a certain local area, then adjusts and improves it by drawing experiences and lessons from local practices, and finally generalizes it nationwide.

It is extremely meaningful for regions and cities like Oxfordshire and Chengdu to have been pioneers to explore how to develop and govern the new economy. We are looking forward to conclude the experiences and practices from them and generalize it to other cities worldwide, which help to provide equitable opportunities for each participant during economic growth and achieve shared prosperity.

Preface

Mr. Marco Kamiya

Senior Economist, Knowledge and Innovation Branch, United Nations Human Settlements Programme (UN-Habitat)

It is with immense pleasure that I introduce the Discussion Papers, *Future Cities, New Economy, and Shared City Prosperity Driven by Technological Innovations*. This collection of articles, from the foremost minds in urban development, technological innovation, finance, design, and sustainability, has come at a much-needed time in our societal timeline. Climate change, just one of our many cross-disciplinary challenges, threatens our ways of life and compounds the societal, infrastructural, and economic problems that we have, for decades, struggled to ameliorate. Human ingenuity remains the sole factor that has kept our global society persevering, and the time has come for us to use this endowed skill to merge the fields of technologic innovation, sustainability, and urban development.

The new Urban Knowledge and Innovation Branch at UN-Habitat, in calling for such a merging of thinkers, has begun its functions with thoughtfulness and enterprise. This Branch of UN-Habitat is bound to contribute greatly to our global challenge of achieving the Sustainable Development Goals. We must tackle our problems with intelligence, hope, and good conscience. The time for technological, innovative thought is now.

Thank you again to our contributors. In these challenging times, it is encouraging to read such forward thinking ideas that stretch across the globe. I implore the readers to take their time with each article, as the intellectual enrichment these papers offer is worth the meticulousness of such a read.

Message from Chief Editor

Dear Readers,

It is with great pleasure that I present this special issue of Discussion Papers titled, *'Future Cities, New Economy and Shared City Prosperity Driven by Technological Innovations'*. This publication seeks to explore the opportunities and challenges provoked by innovative technologies in the ever-changing urban context. The launch of this publication coincides with the 10th World Urban Forum (WUF10), the most prominent global forum on urban issues in the world, occurring in Abu Dhabi in 2020.

The United Nations Human Settlement Programme (UN-Habitat), the convener of WUFs, is the specialized United Nations agency for human settlement and sustainable urban development. Through UN-Habitat's Strategic Plan 2020 - 2023, the agency has embraced and institutionalized innovation as a core value of the organization.

The United Nations Secretary-General, Mr. António Guterres, has highlighted the need for the UN as a unified organization to embrace new technologies and to foster innovations that help achieve the Sustainable Development Goals (SDGs). It is the United Nations' responsibility to build an architecture that promotes and activates innovation partnerships as well as creates a culture of innovation worldwide[1].

This publication delivers an interdisciplinary approach from professionals and scholars working in government, the UN, academia, scientific research, and private sector. The purpose of this publication is (1) to raise awareness on new technological innovations and how these changes affect urban infrastructure and the quality of living of urban dwellers; (2) to enhance collective knowledge on different user cases of new technologies in cities and the potential benefits and risks; and (3) to call for collaboration and collective actions from all cities to smartly use and govern new tech solutions for a safer, more inclusive, and more prosperous urban environment.

Ms. Lei Guo

Project Lead, Innovation Initiatives
United Nations Human Settlements Programme
(UN-Habitat)

1. UNIN, "Fostering Innovation," UN Innovation Network, https://www.uninnovation.network/fostering-innovation, accessed February 4, 2020.

Principal Authors

Michael Keith
Director of Oxford Programme for the Future Cities and Peak Urban, Oxford University

Michael Keith is Director of the PEAK Urban Research programme. Until October 2019, he was the Director of the Centre on Migration, Policy and Society (COMPAS) at the University of Oxford. He is the co-ordinator of Urban Transformations (The Economic and Social Research Council portfolio of investments and research on cities), and Co-Director of the Oxford Programme for the Future of Cities. His research focuses on migration related processes of urban change. His most recent work is the monograph 'China Constructing Capitalism: Economic Life and Urban Change'. His next, 'Urban transformations and public health in the emergent city' will be published in 2020 by Manchester University Press. Michael Keith was also a council leader in east London and chair of the Thames Gateway for seven years, involved in over 17 major urban regeneration programmes as either chair or director in the 1990s and 2000s.

Jian Gao
Postdoctoral Research Fellow in the Center for Science of Science and Innovation (CSSI), Kellogg School of Management, Northwestern University

Jian Gao is a Postdoctoral Research Fellow in Kellogg School of Management, Northwestern University, USA. He obtained a PhD in computer science from the University of Electronic Science and Technology of China. He was a research assistant in the MIT Media Lab, Massachusetts Institute of Technology (MIT), and a visiting scholar in Boston University. His research interests lie in computational social science, network science, economic complexity, and collective learning. He is currently working in the interdisciplinary field named Computational Socioeconomics.

Tao Zhou
Professor in the University of Electronic Science and Technology of China, Executive President of the Institution of New Economic Development

Professor Zhou is primarily engaged in research on statistical physics and complexity. He has published more than 300 papers cited in SCI journals such as Physics Reports, PNAS and Nature Communications, with over 22,000 citations and an H Index of 70. He won the First Prize of Natural Science awarded by the Ministry of Education in 2009, and the 12th China Youth Science and Technology Award in 2011. He is also listed as a 'Most Internationally Influential Chinese Scientist (Physics and Astronomy)' by Elsevier for four consecutive years since 2014. Professor Zhou was elected as a Standing Member of the 12th China National Youth Federation and served as the Deputy Director of the Working Committee of Science and Technology Sector in 2015. He was honoured as one of the Top Ten Scientific and Technological Innovation

Figures of China in 2015 and won the National Innovation Award in 2017. He has been a member of the Standing Committee of the Sichuan Provincial Political Consultative Conference since 2018.

Quanhui Liu

Researcher in the Institute of New Economy of Development Research Center of Chengdu

Mr. Liu serves as a Researcher in the Institute of New Economy of Development Research Center of Chengdu, Sichuan province, China, where he provides the suggestions for the company and the local government based on data analysis and the modelling. At the same time, he is an associate professor in the college of computer science in Sichuan University. He obtained a doctoral degree in computer science in the University of Electronic Science and Technology of China. His research mainly focuses on epidemic spreading, computation social science and data science.

Hui Zeng

Senior Researcher at WeBank AI

Hui Zeng is senior researcher of the AI Department at WeBank. His research focuses on AI practices, AI and Alternative Data in sustainable finance and ESG investment, and smart cities.

He was the former Director of Technology Development at CAUPD-Alibaba UrbanX Lab and obtained the Excellent Scholar of Vigorous Water Program by Aliababa Research Institute. He is involved in AI CITY solutions and digital platform development for Shanghai, Sanya, Chongqing, Hangzhou, Chengdu and Beijing and contributes to Future Cities and New Economy Research Project for UN-Habitat.

He was the head of the Beijing Office for the AI-related fund, Linear Capital and awarded the Global Youth Delegate for CSR in 2014 by UN Global Compact and Tencent Finance News. Prior to that, he worked for Cisco Strategic Consulting, Jiuding Capital, UNDP, and Tsinghua University Financial Engineering Institute, covering the process of management and due diligence of billions of assets. He participated in the research of Guidelines for Green and Smart Urban Development for China Development Bank Capital.

Mingxiao Zhao

Co-founder of Institution of New Economic Development

Ms. Mingxiao Zhao used to work in international consulting firms and has rich experience in industrial transformation and urban consulting, including providing industry planning of digital transformation, top-level

design of smart cities, industrial suggestions and development references for governments and non-profit organizations in Beijing-Tianjin-Hebei, Yangtze River Delta and Chengdu-Chongqing city clusters.

Now, she is committing to help local governments to adapt to the digital trend and develop urban strategies and policies to foster new growth drivers and respond to disruptive challenges, such as helping cities to improve business environments and providing decision-making reference for the development of emerging industries. She also works with MSMEs to build proper business models, cooperate with partners, explore application scenarios, and enhance brand influence. Mingxiao Zhao worked with UN Women and other NGOs in efforts to conduct research and promote the achievement of the SDGs.

Baolin Cao

Director of Operations at the Institution of New Economic Development

Mr. Baolin Cao is the Director of Operations at the Institution of New Economic Development. He graduated from Chongqing University of Posts and Telecommunications with a master's degree in computer science. His areas of expertise mainly include digital transformation, urban planning, and advanced technologies. In addition, Mr. Cao possesses extensive experience in providing consulting services to municipal governments and state-owned enterprises.

Gerhard Schmitt

Director of Singapore-ETH Centre, Principal Investigator of Big Data Informed Urban Design and Governance project, Cooling Singapore project, and Digital Underground project

Gerhard Schmitt is Professor of Information Architecture at the Swiss Federal Institute of Technology Zurich (ETH Zurich). He started his research at Carnegie Mellon University with the development of intelligent design support systems using artificial intelligence methods. He is now the Director of the Singapore-ETH Centre SEC, ETH Zürich's Science Hub in Asia. As Lead Principal Investigator, he established the Simulation Platform at the Future Cities Laboratory in 2010, followed by the Responsive Cities Scenario and the Big Data informed Urban Design project in 2015. Since 2018, he has led the intra-institutional Cooling Singapore urban climate design project with groups of scientists from ETH, MIT, TU Munich, and the National University of Singapore with the strategic goal to mitigate the Urban Heat Island effect in cities as part of a new science of cities. As Vice President for Planning and Logistics of ETH Zurich, he initiated the development of a third virtual campus, named ETH World with an international master plan

competition in 2000. In 2003, he and his team devised the concept for Science City to transform ETH Hönggerberg into a campus of interaction between society and science. In 2010, Gerhard Schmitt received the European Culture of Science Award for ETH Science City. The Massive Open Online course series on Future Cities that he and his team developed since 2014 reaches to 130'000 students in 180 countries.

Jaideep Gupte

Fellow of the Institute of Development Studies, University of Sussex; and Challenge Leader, Global Challenges Research Fund (GCRF), UKRI

Jaideep Gupte is Fellow of the Institute of Development Studies, at University of Sussex, where he leads the Cities Cluster. Jaideep is currently seconded to lead the Cities and Sustainable Infrastructure portfolio of the Global Challenges Research Fund (GCRF), UKRI. Jaideep's research interests include the governance and infrastructural implications of urban violence, poverty, and development in relation to the built environment. Jaideep uses multi-disciplinary approaches and local data to understand material, temporal, and political aspects of urban informality.

With his research, Jaideep aims to highlight the everyday experiences of the most marginalised urban residents. He has conducted primary research in countries such as India, Bangladesh, Nepal, Sudan, and Nigeria. He has also served as a consultant for DFID; UNICEF; local authorities in South Asia, Latin America, and sub-Saharan Africa; and several NGOs.

Jaideep's research has received funding from the ESRC, DFID, the European Commission, among others. He is currently the Principal Investigator on 'Smart Data for Inclusive Cities' funded by the European Commission, Executive Director of the 'Mobile Training Platforms for City Police' funded by the World Justice Project, and was the Principle Investigator on the recently concluded 'Informal work and wellbeing in South Asia' funded by the South Asia Research Hub, DFID.

Jaideep has a DPhil in Politics from the University of Oxford (St. Antony's College), an MPhil in Development Studies from the University of Sussex, and a BA (Hons.) in Economics from Simon Fraser University. Jaideep's research has received the Global Development Network Medal for Outstanding Research, Category: Rule of Law. He was formerly a Prize Fellow of the Urban Design Research Institute, Mumbai.

Saiful Ridwan

Chief Enterprise Solutions Officer at the United Nations Environment Programme (UNEP)

Based in Kenya, Saiful Ridwan is responsible for the identification, creation, development, and delivery of business and emerging information technology solutions to support

the goals and mandate of UNEP. Holding a first degree in Architectural Design from Indonesia, and a Master of Science degree in Information Technology from UK, Saiful has over 30 years of international experience in various fields of information technology within diverse sectors, including the UN, private sector, and academia. A national of Indonesia, he designed and produced the first ever current affairs webzine, Tempo Interaktif, in his country back in 1996, at a time when conventional media was tightly controlled by local authorities and web technology was in its infancy. An avid collector of photos of environmental / green bins, Saiful currently focuses on the implementation of emerging technologies for environmental protection.

Harrison Simotwo
Associate Programme Management Officer, UNEP

Harrison Simotwo is a nascent environmental sustainability and development professional with extensive experience at the international level, in a range of fields, including sustainable development, development policy, public-private partnerships, program/project design, management and monitoring, evaluation, reporting and learning. In his current roles as the Associate Programme Managemen Specialist at UNEP Regional Office for Africa, Harrison supports the delivery of UNEP's mandate across the 54 African countries. Additionally, Harrison is an author and has a Master of Arts in Environmental Planning and Management, and a Master of Science in Biology of Conservation, with previous experience in government, civil society, and private sector in the geographies of Africa (Kenya), Asia (Japan) and Eastern Europe (Poland).

Pietro Visetti
Environmental Technology Intern, UNEP

Pietro is a recent addition to UNEP's Enterprise Solution Section Team. He conducted his master studies in Environmental Economics at Wageningen University and Research in the Netherlands, and he studied Neoclassical Economics and International Finance in Geneva.

In 2019, Pietro also became one of the few selected members of the Climate Knowledge and Innovation Community of the European Institute of Innovation and Technology (EIT). Prior to joining UNEP, Pietro worked for an environmental consultancy firm where his focus was on natural capital accounting and ecosystem services valuation.

Keli Zhu
Executive President of China Institute of New Economy of Development Research Center of the State Council of China

Mr. Keli Zhu obtained his doctoral degree in economics from Chinese Academy of Social Sciences. He became a member of the Youth Think Tank of the Central Government Departments and was selected as National Key Talents Programme.

He was the chief editor of the New Economy Weekly, the academic secretary of the National Economics Foundation, and the President of Zhongshang Thinktank of the Ministry of Commerce. He has been committed to the promotion of regional innovation and development for many years and is the strategic adviser of new economy for Chengdu and other cities.

George Economides

Team Leader for Connected and Autonomous Vehicles of Oxfordshire County Council

In 2017, George Economides joined the Oxfordshire County Council's Innovation and Research Team, as Team Leader in Connected and Autonomous Vehicles, the first CAV-dedicated position from a local authority. He is interested in Connected and Autonomous Vehicles, Mobility as a Service, Demand Responsive Transport, and Internet of Things. He is leading Oxfordshire County Council's CAV Team and projects, such as DRIVEN, MultiCAV, OmniCAV, etc.

Zhiyong Fu

Associate Dean of China-Italy Design Innovation Hub at Tsinghua University, Vice-director of China Innovation & Entrepreneurship Education Research Center, the member of Tsinghua University Innovation and Entrepreneurship Teaching (special) Committee

Zhiyong Fu is Associate Professor of Information Art and Design Department, Academy of Arts and Design, Tsinghua University. During January to April 1998, he was a visiting professor of Kansei Evaluation special research project at Tsukuba University, Japan. He was a recipient of the National Award for New Century Excellent Talents (2006). During August 2008 to August 2009, He was a visiting scholar in school of design at Carnegie Mellon University, USA.

He is associate dean of China-Italy Design Innovation Hub, vice-director of China Innovation & Entrepreneurship Education Research Center, and a member of Tsinghua University Innovation and Entrepreneurship Teaching (special) Committee. He has served as the Secretary-General in China Information & Interaction Design Committee (IIDC) since 2014, and the Vice President of The International Chinese Association of Human-computer Interaction ICACHI from 2016.

His research interests include information and interaction design, service design, social innovation, and smart city design research. He is the leader for multiple national and international research projects, and published papers in key international conferences in HCI and design, such as ACM Ubicomp, HCII, IASDR, DESIS and DMI. He was the member of subcommittee of Design of ACM CHI 2014 and 2018, 2020. He was board member of Cross-Culture Design Sub-committee at HCII 2012-2020. He is main organizer and planner of 2014 to 2020 China-US Young Maker Competition initiated by Chinese Ministry of Education.

He is currently in charge of Tsinghua AI Innovation & Entrepreneurship Minor, and several research projects to promote the innovation and entrepreneurship education in China.

Peter Scupelli

Director of the Learning Environments Lab, Nierenberg Associate Professor of Design, Carnegie Mellon University

Peter Scupelli's current research focus is on learning environments. Peter teaches both undergraduate and graduate-level courses. He currently teaches required courses such as: Environments Studio I: Form and Context, Graduate Design Studio II, and Dexign Futures. Peter's teaching and research focus on two fundamental topics necessary to bring aspects of Transition Design to design practice: aligning short term design action and long-term vision goals and embedding values into design processes. In Dexign Futures students learn to combine Design Thinking with Futures Thinking to align short and long term time horizons. In Design Ethos and Action, he teaches how to embed values such as gender equality and sustainability into everyday life and organizations and how to redirect design practice towards sustainment.

Peter's training and career path link architecture, interaction design, and human-computer interaction research. He completed his Ph.D. at the Human-Computer Interaction Institute in the School of Computer Science at Carnegie Mellon University. His dissertation focused on how the architecture of the built environment around large schedule displays and nursing control desks support coordination services in surgical suites.

Jianjun Xu

Executive Deputy Dean and Assistant Professor of the Institute of New Structural Economics at Peking University

Dr. Jiajun Xu is an Assistant Professor and the Executive Deputy Dean of the Institute of New Structural Economics at Peking University. Dr. Xu acts as the General Secretary of the Global Research Consortium on Economic Structural Transformation (GReCEST). Dr. Xu worked as a Junior Research Specialist at the United Nations' High Level Panel Secretariat on the Post-2015 Development Agenda responsible for the research on development financing and South-South Cooperation. She worked as an international consultant on debt sustainability in the World Bank and productive capacity building for least-developed countries at the United Nations Committee for Development Policy Secretariat. She has published in peer-reviewed academic journals such as Journal of International Development and Institute of Development Studies Bulletin. She is the guest editor of China Economic Review. She is the lead author of Global Development Financing Report (2015). Her academic monograph Beyond US Hegemony in International Development was published by Cambridge University Press in 2017. Dr. Xu holds a DPhil (PhD) from the University of Oxford.

Xinyue Wu

Project Executive Director, the Inaugural New Structural Economics Development Financing Research Programme, Institute of New Structural Economics at Peking University

Xinyue Wu obtained MA Political Economy from King's College London. Before joining INSE, she served as a UNV for the UNDP-IPRCC project on South-South cooperation. At INSE, she worked as the project executive director for the inaugural New Structural Economics Development Financing Report. Currently, she is leading the state development project of the Kaduna State, Nigeria. In addition, Xinyue Wu was the consultant for a policy-oriented research program commissioned by China Development Bank. Her focus areas include development finance, structural transformation, green transformation, and global value chain. She has publications on "Mapping Development Finance Institutions Worldwide: Definitions, Rationales and Varieties," "China Africa Industrial Capacity Cooperation under the Belt and Road Initiative," and so on.

Haishan Wu

Vice General Manager of AI Department at WeBank

Dr. Haishan Wu is the vice general manager of the AI Department at WeBank and was the Director and AI scientist at BlackRock. Previously, he was the Chief Data Scientist of Heyi Ventures, senior data scientist of Big Data Lab at Baidu. He led a team focusing on spatial-temporal big data mining and developed products ranging from smarter city, location-based service to social-economic research. His research was not only published in prestigious journals and conferences, but also widely featured by major media outlets including MIT Technology Review, New Scientist, Discovery Channel, NPR, Bloomberg, BusinessWeek, CNN Money, The Economist, Wall Street Journal, CNBC, Forbes, NPR, Washington Post and so on. His research on data driven ghost city mapping was selected as Best of 2015 by MIT Technology Review. In 2016, he worked with UNDP on measuring poverty with big data for China's poverty alleviation purposes. Haishan earned his PhD degree from the computer science department of Fudan University in 2011. He was a postdoc researcher in Princeton University from 2013 to 2014. Haishan was recognized as 35 Innovators Under 35 in China by MIT Technology Review in 2017. He was also recognized as one of the Top 50 data scientists in China by CBN.

Lei Yin

Senior expert of AI Department at WeBank

Dr. Lei Yin is senior expert of the AI Department at WeBank. Dr. Lei Yin graduated from Beijing Institute of Technology. Upon graduation, Dr. Yin first joined Baidu and worked as the head and senior architect of Baidu Huiyan. He then worked as the lead technology director at Qunar. Dr Yin co-founded and performed as CTO at SensTech, a startup focusing on alternative data and

AI. Currently, Dr.Yin is working in WeBank as the lead technology director and senior AI scientist of the AI department focusing on the Asset Management development, mainly responsible for alternative data and AI-driven and investment products, including ESG product research and development. During his doctoral study and work, Dr. Yin published more than 10 papers, including 3 papers in SCI journals, and 11 invention patents, including 1 international patent.

Shantian Cheng

Dr. Shantian Cheng is product design expert of the AI Department at WeBank

He worked as Risk Quant Manager at DBS Bank and Research Associate and Validation Team Lead at Risk Management Institute at NUS, involving derivative pricing and greeks model validation and review and market, counterparty, and liquidity risk model development. He obtained PhD in Applied Mathematics from Nanyang Technological University, Singapore.

Deyi Wu

Senior researcher of AI Department at WeBank

Prior to this, she worked as ETF specialist at Blackrock and as Capital Analyst at UBS. She specializes in ESG product design.

Bingnan Yin

Product manager of AI Department at WeBank

She is responsible for product design, project management and AI commercialization. She obtained a postgraduate degree in Electronic Commerce and Internet Computing from The University of Hong Kong.

Marco Kamiya

Senior Economist, Knowledge and Innovation Branch, UN-Habitat

Marco Kamiya was previously the head of the Urban Economy and Finance Branch, now transitioning to Knowledge and Innovation at UN-Habitat. He led global operational and normative work on urban economy and municipal finance. Working with cities, he supports financing methodologies related to planning, participatory approaches, and infrastructure finance. Previously, he occupied senior positions at CAF Development Bank of Latin America from Caracas, the Inter-American Development Bank from Washington DC, and with PADECO Co., Ltd in Tokyo. He studied Economics in Lima and Tokyo, and International Development at Harvard University.

He has published “Economic Foundations for Sustainable Urbanization” (with Serge Salat, UN-Habitat & Morphologie Institute Paris), “Finance for City Leaders handbook” (with Le Yin Zhang, UN-Habitat and University College London), and the “Global Urban Competitiveness Report” that appears annually in Chinese and English.

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We thank and greatly praise the WeBank AI Department Moonshot Team for their unique technical support.

Editing Team

Lei Guo

Ms. Lei Guo is the Lead of Project for Innovation Initiatives previously at the Urban Economy and Finance Branch, now transitioning to the Knowledge and Innovation Function at UN-Habit. She was acting as the focal point for UN-Habitat with United Nations Innovation Networks (UNIN).

Previously, she worked at United Nations International Children's Emergency Fund (UNICEF) in New York Headquarters as a strategist and a Project Coordinator at United Nations Educational, Scientific and Cultural Organization (UNESCO) in Beirut, Lebanon. In addition, she had entrepreneurial experience in the field of Artificial Intelligence as the co-convener of China AI 30 Forum. She holds a B.A. in Finance and a M.S. in Social Enterprise of Administration with Columbia University in City of New York.

Sonola Onasanya

Sonola works with the Urban Knowledge and Innovation Branch of UN-Habitat. He completed a Master of Philosophy in Engineering for Sustainable Development at the University of Cambridge.

The focus of his dissertation was on solving the issue of solid waste pollution in Lagos, Nigeria. He also holds a BSc in Chemical and Biomolecular Engineering from Georgia Institute of Technology and has worked as an engineer in plastic and bioethanol research.

Hui Zeng

Hui Zeng is senior researcher of the AI Department, WeBank. His research focuses on AI practices and Alternative Data in sustainable finance, ESG investment and smart cities. He was the former Director of Technology Development at CAUPD-Alibaba UrbanX Lab and obtained the Excellent Scholar of Vigorous Water Program by Aliababa Research Institute. He is involved in AI CITY solutions and digital platform development for Shanghai, Sanya, Chongqing, Hangzhou, Chengdu and Beijing. He contributes to Future Cities and New Economy Research Project for UN-Habitat.

He was head of the Beijing Office for the AI-related fund, Linear Capital and awarded the Global Youth Delegate for CSR in 2014 by UN Global Compact and Tencent Finance News.

Mingxiao Zhao

Ms. Mingxiao Zhao used to work in international consulting firms and has experience in industrial transformation and urban consulting, including providing industry planning of digital transformation, top-level design of smart cities, industrial suggestions and development references for governments and non-profit organizations in Beijing-Tianjin-Hebei, Yangtze River Delta and Chengdu-Chongqing city clusters.

Now, she is committing to help local governments to adapt to the digital trend and develop urban strategies and policies to foster new growth drivers and respond to disruptive challenges, She also works with MSMEs to build proper business models, cooperate with partners, explore application scenarios, and enhance brand influence. Mingxiao Zhao worked with UN Women and other NGOs in efforts to conduct research and promote the achievement of the SDGs.

How to interpret a Contemporary City?

This is not only a question for city policymakers and developers to think about, but also actively calls for the data scientists to participate. From the recent waves of urban expansion and changes of the city, what is the rule or pattern of city development? Resource shortages caused by population explosion, financial risks contributed by climate change, uneven distribution of information services... we are raising a series of questions for cities. However, questions arise when we also get an access to the opportunities from breakthrough. Joseph E Stiglitz, the winner of Nobel Prize in Economics and former Senior Vice President and Chief Economist at World Bank, stated his prediction about two elements impacting global economy in 21st century, the one is the technical revolution in the United States, the other is urbanization in China.[1] In fact, backing to global context, urban development is always accompanied by the progress of technology. Standing on the transformation point of urban prototype, we are confronted with two paths, the one is full of thorns, the other is distant. Technology and humanity eventually meet at the top of the mountain through these two paths.

Therefore, both understanding how technology reshape city development, and interpreting plus quantifying cities from the perspective of data will be the “golden key” to answer sustainable development in the forthcoming decades

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SECTION 1

TRADITION TO MODERNITY: CITIES FACING TECHNOLOGICAL TRANSFORMATION

Maybe your watch is making your insurance so expensive

Technological change and city transformation

Michael Keith
Oxford University

Technological change disrupts. Disruptions have uncertain consequences, generating massive benefits and unexpected challenges. To maximise the former and mitigate the latter, cities must balance forces that pull in different directions, recognise the trade-offs such balancing demands, and be flexible and astute enough to capture the opportunities technological change can engender. Climate, air, open space, culture, and much else in the city are shared in what are known as forms of urban commons. But the city also depends on the freedoms of individuals to think differently, to innovate and, to experiment. And equally in these forms of experimentation, the ability to monetise ideas, practices, and technological change demand a security of forms of property and market reward. These tensions between the commons, rights, and property can be illustrated by three moments of technological disruption; the defibrillator, the apple i-watch, and the uber ride sharing app.

The history of each of these objects describes a process of disruption. Technology disrupts through dislocating the architecture of one or more parts of the city system. But a city is never a singular system. It is a multiplicity, invariably a system of systems. Health systems, economic systems, social systems, systems of flow, and metabolic systems - all are interdependent in the urban context, meaning that cities are fundamentally open rather than closed systems. The pieces of the system themselves are subject to change. There are many consequences of this, but, for the purpose of this intervention, it is worth stressing three facets of complex open systems in understanding the power of technological change to shape urban futures.[1]

Facet 1: Emergence and the defibrillator

Open systems are characterised by emergence. Emergence is a concept that crosses the humanities, natural sciences, and social sciences. Emergence is the property of complex systems that reconfigures the relations between the constitutive elements of the system itself. Emergence qualifies the power of prediction. Recognising that repetition is the property of stable systems, the attempt to model and to project from trends remain a powerful tool for the analysis of human behaviour and identify patterns in increasingly data rich urban settings. Paradoxically, in the 21st century, the exponential increase in the ability to predict behaviour in real time means that we know more and more about the short

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How such mobility futures might shape future cities depends on the manner in which the technologies are regulated and nudge human behaviour of tomorrow's 'cityzens'

term at the same time as the power and pace of disruptive technologies change the speed and fundamentals of city logics and thus implying that we know at times less and less about the longer term beyond a matter of two to three decades at most.[2] Recognising the exponential growth of digitised and big data consequently both empowers the new urban sciences and sets horizons on their ability to predict city futures.

Acknowledging that prediction lasts no longer than the stability of the system itself is a matter of scientific accuracy, a recognition of the imperative to identify the mathematics of disequilibrium alongside assertions and observations of tendency towards equilibrium

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in system working.[3] Balancing the power of the former with the humility of the latter is a matter of judgement that invokes questions of scale and temporality; the detail of divergence that we search for, the length of time over which we measure the urban system. But the fundamental recognition that emergent systems have the power to undermine their own long-term stability demands an ethical as well as epistemological engagement with real world claims both to know the metropolis and to make scientific observations about how we think about urban futures.

In the last decade, technological innovation created defibrillators that were both cheap enough to be considered for wider public use and rapidly proliferated across multiple locations in cities of much of the globe. Between 2005 and 2013, the number of defibrillators in Japan alone went up from just below 11,000 to over 400,000.[4] For every minute that goes by where a victim of Sudden Cardiac Arrest does not receive treatment, their chance of survival decreases by 10%. If defibrillation through a defibrillator occurs within 1 minute of the victim collapsing, the victim's survival rate increases to 90%. The defibrillator consequently disrupts the rhythms of speed in the city and changes the relationship between hospitals and patients suffering major cardiac incidents, reflecting increasingly the importance of public access to defibrillators more than blue light services sending ambulances from hospitals across the surface of the city through commonly congested roads. [5]

Facet 2: Path dependency, lock ins and the uber app

But one problem with all public health systems is that technology tends to move faster than real estate markets. In the global north, the geographical spread of primary care facilities can be defined optimally for stroke, cancer, or lung functions, but this definition will always be subject to and handicapped by both the distribution of medical real estate and the capacity of latest technologies. In China, the opening-up process after 1978 led to the decline of public investment in primary care and a massive increase in private insurance and in the savings needed to pay for insurance.[6] But excessive savings diminish consumption that undermines economic growth and, more recently, for reasons that are both economic and egalitarian, the pooled risk of increased health insurance in China aims to reduce providential savings and increase domestic demand and economic growth. More pragmatically and innovatively in India, Delhi city government appropriates the logic of urban squatting to claim the city as a commons for innovative Mohalla clinics, 'pop up' constructions addressing immediate health needs in extemporised structures.[7] The particular histories of China and Europe show contrasting ways in which health systems view the city as commons but can become locked in to geographically and historically specific distributions of real estate reflecting existing property logics, outdated responses to yesterday's technological fixes.

Likewise, cities globally have been characterised as locked into car ownership, prompting urban sprawl and lowering densities through the flight to the suburbs. Ride sharing apps such as Didi and Uber are at times seen as promoting solutions to the dependency on personal car ownership. But such apps depend in part on the structure (and the path dependencies) of city markets. In unregulated city markets, such as Johannesburg and Mexico City, the uber app disrupts rapidly. In more regulated markets, such as Paris, New York, or London, the disruption is less so. And the company itself monetises the app through the temporalities of financialised investment that speculates on the mobilities of future

5.32 billion US dollars

Uber's largest ever single quarterly loss was posted in 2019

cities. In 2019, Uber recorded the largest ever single quarterly loss of $5.32 billion dollars. Investors were betting on the propensity of the disruption to monetise different data driven modes of mobility down the line mediated by products such as food and services delivered possibly by Uber's pioneering development of driverless shared vehicles. Data as the new oil. But Uber's driverless cars might generate more sprawl if they create comfortable working environments for longer rides or potentially more dense urban living if they encourage people to value the freedoms of proximity to central city facilities mediated by easier mobility, creating new environmental dilemmas.[8]

How such mobility futures might shape future cities depends on the manner in which the technologies are regulated and nudge human behaviour of tomorrow's 'cityzens', which leads to a third facet of open systems, the behavioural adoption of different technologies

Facet 3: Adoption and commensuration and the Apple i-watch

On March 18, 2018, Elaine Herzberg was alleged to be the first pedestrian mortality of an autonomous vehicle when struck by a self-driving Uber test vehicle in autonomous mode in Tempe, Arizona. Driverless cars generate new ethical dilemmas. How do we calculate their actuarial risk and people's response to their presence in tomorrow's cities? How do we value the lives of the misbehaving pedestrians jaywalking, the wobbling bicycles, and the elderly pedestrian in moral trolley dilemmas for the 21st century when sharing streets with autonomous vehicles?

Technological disruption inevitably raises such ethical as well as behavioural and economic questions.

Impacts of technological disruptions depend on how much behaviour changes or, at times, on how much behaviour can be 'nudged' to change. The Apple i-watch is one example of a device that nudges people to measure exercise regimes to promote healthy lives. But it is also the case that private insurance companies incentivise self-monitoring through such devices. In the UK one company offers to pay for a £350 Apple i-watch as part of a deal that pays for private health insurance and then registers activity data with the company. This may appear innocent until the data collected by the insurance company aggregates data upwards but also personalises such data downwards and translates it into measures of personalised actuarial risk and premium payment levels for the insurance company. In this context, actuarial risk services both a rational data calculus for private insurance (data as oil again) but also simultaneously surfaces a public concern for regulation of corporate involvement in public health.

How do we reconcile the rights of the individual and the commodity value of the big data they contribute with devices such as the i-watch? In part, this raises measurement of different regimes of value and worth; how we attempt to make them commensurable. How do we prioritise competing interests of mobility, public health, economic prosperity, or alternative measures of social need?

The overlap of ethical judgements, economic demands, collective needs, and individual rights makes the trade-offs involved in such commensuration visible.

Complex systems logic demonstrates why seeing like a city demands recognition of geographical specificity and path dependent social settlement, opening contextual opportunities of place that render bespoke local city 'clumsy' solutions to 'wicked' urban problems more plausible.[9] Cities of the global south have the potential to leapfrog the 20th century lock ins of car-based urbanism and wasteful city metabolisms of water and waste. But equally, different histories of underdevelopment weigh heavily in specific parts of the world; alternative visions of the good life balance the imperatives of the city commons, the architecture of markets, and the freedoms of regimes of rights differently. But what they can share is a recognition of the powers of the new urban sciences and the capacity to predict in real time (P), the contingencies of emergence in complex systems (E), which are adopted differently (A) according to distinct local systems of commensuration that demand an experimental disposition to urban futures that demands innovative knowledge exchange across urban systems (K). This disposition of 'PEAK Urban' creates a frame through which technological change might be harnessed by cities that are reflexive and flexible in their response to technological disruption, both optimistic and realistic about the propensity for technological change to shape their futures.[10]

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Big data kills the virus

Computational Socioeconomics: A data-driven framework for quantifying progress towards achieving the Sustainable Development Goals (SDGs)

Jian Gao, Tao Zhou, Quanhui Liu
Insitution of New Economic Development

The improvements of data acquisition and processing capabilities, as well as artificial intelligence and statistical mechanics, have rapidly and significantly changed the methodology of social and economic research. The recent paradigm shifting of social science driven by big data and artificial intelligence provides promising and novel data-driven methods for measuring the progress of Sustainable Development Goals (SDGs). This shift affects areas ranging from no poverty to good health and well-being, from gender equality to quality education, and from economic growth to innovation and infrastructure. Governments at both national and regional levels can benefit from leveraging new methods under the framework of Computational Socioeconomics[1] to better assess their progress towards sustainable development over space and time with a higher efficiency and a lower cost.

New Methodology Shifts

Social and economic studies become increasingly dependent on real data. Yet, the traditional way to obtain real data has many limitations. For example, larger-scale and more precise data usually consumes huge resources and lacks timeliness. Fortunately, thanks to the digital wave that swept across the world in recent decades, social and economic researchers face an unprecedented opportunity to develop a quantitative methodology.

Data in the processes of socioeconomic development and human activities are recorded by an increasing number of sensing devices, online platforms, and other data acquisition terminals such as remote-sensing satellites, mobile phones, social media platforms, and online trading platforms.[2, 3] On the other hand, these data are of larger size, almost in real time and with higher resolution, can reduce the sparsity and bias in small-size data as well as reduce the invisible parts in the developing processes. Therefore, based on these large-scale novel data, we can in principle make great progress in perceiving socioeconomic situations, evaluating development progresses, predicting future social and economic trends, and so on.[4]

The increasing volume and diversity of novel data lead to methodological changes in two aspects. Firstly, simple statistical tools are not suitable for analyzing unstructured data such

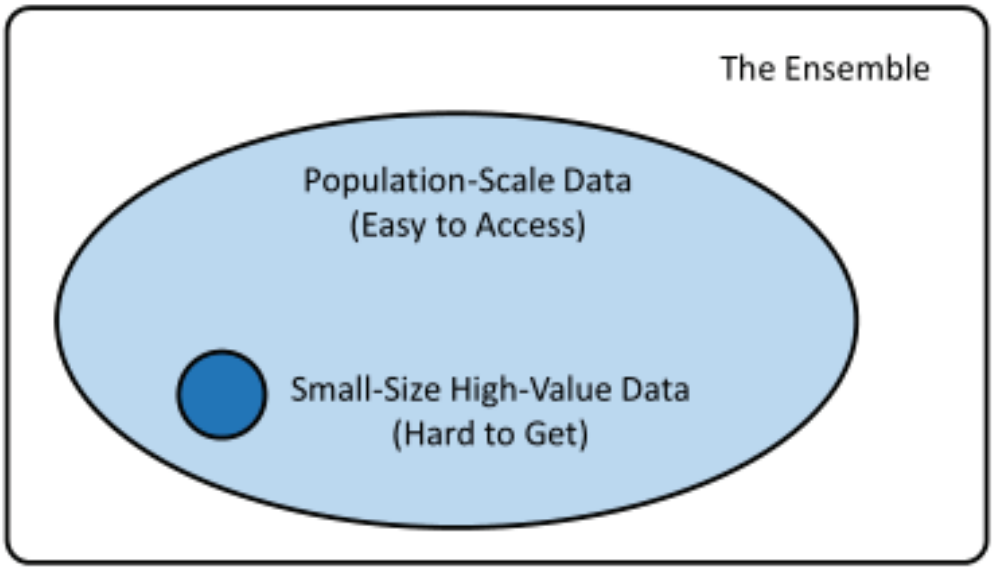


Figure 1. Illustration of ensembling novel data in the computational socioeconomics framework. © **Gao, Zhang & Zhou. Physics Reports, 2019**

as street view images and textual contents. Researchers are in serious need of more advanced techniques of data mining and machine learning.[5] Secondly, with population-scale data, one can concentrate on a small sampled subset and add high-valued new dimensions of data.

New data dimensions can be obtained through traditional means such as a questionnaire survey. A model can be trained based on the small sample to infer new dimensions from the original ones. After applying the model to the whole dataset, one can obtain new data dimensions for all individuals.

This method integrates some routine methods like sampling, labeling, and surveying, while it is more powerful in practice. For example, it is relatively easy to obtain the population-scale data on mobile communication and mobility, while it is very hard to know the household income of every family without compiling a population-scale economic census. Under the new framework, we first obtain household incomes of some families via routine questionnaires. Then, using the small dataset, we train machine learning models to predict household income of a family based on the mobile phone data of the family members.

Although the inferred data is not perfect, it can be very close to the real data under a certain well-designed algorithm. Notice, a significant advantage is that the high-value data for almost every individual can be obtained at a very low cost. Combining the accessible population-scale data, a small sample of high-value but hard-to-get data, and a properly selected or well-designed algorithm to infer the high-value data for individuals other than the sample is a novel and representative method in the computational socioeconomics study (Figure 1), showing the deep integration of social science and computer science methods.

Nowcasting Poverty and Growth

Revealing the status of social and economic development in a near real-time manner and with a lower cost is one of the long-standing problems that hinders the effects towards Sustainable Development Goals (SDGs). To approach the goals of no poverty, the first step is to accurately map the spatial distribution of poverty. New data and tools introduced in computational socioeconomics have been utilized to better reveal, explain and predict global poverty and economic growth, such as data from remote sensing (RS) and mobile phone (MP).

High resolution data from RS, for example, nighttime lights (NTLs) satellite imagery, has been used to supply information about economic activity, especially in developing countries where traditional economic census data are insufficient. NTLs data can provide an unambiguous indication of the spatial distribution of economic development. For example, Jean et al.[6] applied deep learning algorithms to learn the relationship between NTLs and daytime satellite imagery. The former can predict the wealth distribution while the latter contains rich information about landscape features. The image features extracted from the daytime imagery can explain up to 75% of the variation in the average household asset across five African countries. Moreover, the method is able to reconstruct survey-based indicators of regional poverty with high accuracy.

MPs are able to capture an enormous information and provide cost-effective data at the individual level. With MP logs related to consumption and expenditure, socioeconomic status can be inferred by employing machine learning approaches at the aggregated subnational and national levels. For example, Blumenstock et al.[7] presented a novel method to explore the relationship between MP usages and wealth in developing countries. By analyzing the data from Rwanda, they found that household expenditures are positively correlated with MP usages, for instance, in the number of different districts contacted. Moreover, by applying a machine learning approach to analyze the follow-up phone surveys of some individual subscribers, Blumenstock et al.[8] showed that individual wealth can be well predicted and individuals in relative poverty can be accurately identified. Then, they generated out-of-sample predictions for 1.5 million MP users and produced the wealth map of Rwanda at a very high resolution and accuracy. This method is promising to map the distribution of wealth and other socioeconomic indicators for the full national population.

Understanding how economies develop to prosperity is a long-standing challenge in economic growth. Hidalgo and Hausmann [9] proposed a novel index named economic complexity (ECI), a non-monetary metric which quantitatively assesses a country's potential for future economic growth. In particular, a Method of Reflections (MR) is proposed to characterize the structure of ``country-product'' bipartite network in international trade and the variables produced by the MR method can be interpreted as indicators of economic complexity. Empirical results showed that countries' ECIs are highly correlated with their income levels and are predictive of their

Moreover, individual behaviors on social networking platforms have been used to estimate individual personality and mental states such as depression and suicidal intent.

future growth. Later, a statistical approach is employed to define a new set of metrics and to quantify the fitness of countries and the complexity of products. Tacchella et al.[10] showed that this scheme outperforms the International Monetary Fund (IMF) five-year GDP per capita forecast by more than 25% in accuracy, and the method's forecasting errors are predictable. These complexity and fitness measures have been used to quantify the economic complexity and development at different spatial resolutions, such as China's regional economic complexity.[11]

Perception of Regions and Cities

High-resolution data and improved methods allow us to reveal economic activity and socioeconomic status in subnational, regional, and urban scales. For example, indicators derived from both nighttime lights (NTLs) and very high resolution (VHR) imagery have been used to map poverty at fine scales. In particular, novel data from mobile phone (MP) and Google Street Views provide a promising way to the perception of cities and communities.

Slums are common in low- and middle-income countries with poor quality of basic services (e.g., water supply, electricity, and sanitation). Detecting and monitoring slum areas is valuable for implementing policies to improve living conditions. Recently, VHR images have been increasingly used to inventory the location and physical composition of slums. For example, Kit et al.[12] developed the concept of lacunarity to identify slums in Hyderabad,

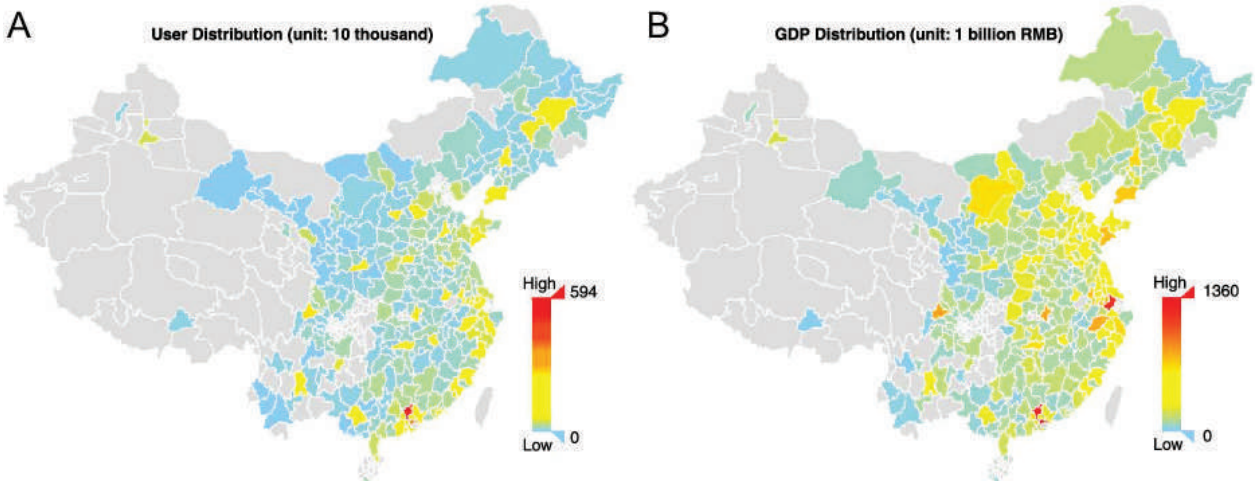


Figure 2. The spatial distributions of the intensities of online activity (A) and the values of GDP (B) in prefecture-level cities of China in 2012. © **Liu et al. Physica A, 2016**

India. The best method can reach an accuracy of 0.8333 in slum identification and can capture the changing patterns of slum areas from 2003 to 2010. Similarly, Kuffer et al.[13] utilized the gray-level co-occurrence matrix (GLCM) variance to distinguish slum areas in VHR imagery and showed that the overall accuracy can be increased to 90% by adding spectral information to the GLCM within a random forest classifier.

Social media (SM) data have been used to track socioeconomic well-beings. For example, based on the registered location information of nearly 200 million Weibo users in China, Liu et al. [14] explored the relationship between online activities and socioeconomic indices (Figure 2). They found that UN is strongly correlated with socioeconomic indices, suggesting that socioeconomic status can be inferred from online social activity at the city-level. Of particular significance, they further proposed a method to detect a few abnormal cities, whose GDP is much higher than others with the same number of registered users. Similarly, with data of friendship information and geo-locations from Gowalla in the US, Holzbauer et al.[15] studied the relations between regional economic status and quantitative measures of social ties. They found that cross-state long ties are strongly correlated with three economic measurements, namely, GDP, the number of patents, and the number of startups.

Crowdsourcing methods and computational vision techniques have been used to measure livability, safety and inequality, to infer the status of urban life, and to quantify the changes of urban streetscapes. For example, Salesses et al.[16] presented a method to measure the urban perception of safety, class, and uniqueness in two US cities and two Austrian cities based on hundreds of geotagged images. They found that the two US cities are perceptually more unequal, and that the spatial variation of urban perception helps explain violent crimes in NYC zones

at zip-code resolution. Later, Naik et al.[17] trained a scene understanding model named Streetscore based on data from an online survey to predict the perceived safety of a streetscape using generic image features. Physical appearances of neighborhoods are not static but changing over time. Naik et al.[18] introduced a computer vision method to understand physical dynamics of cities based on street views at different times. They found that education and population density, physical proximity to city centers, and better initial appearances are associated with physical improvements in neighborhoods.

Deep-learning-based computer vision techniques have been applied to analyze digital imagery, which provides a faster and cheaper alternative of community survey. For example, Gebru et al.[19] proposed a method to estimate socioeconomic trends from 50 million street view images in 200 US cities. They automatically detected 22 million distinct vehicles from images using the object recognition algorithm and then deployed CNNs to determine features of vehicles and classify each vehicle into one of the 2,657 fine-grained categories. Using the resulting data, they estimated race and education levels by training a logistic regression model and estimated income and voter preferences by employing a ridge regression model. Compared to the American Community Survey, their demographic estimates exhibit satisfied accuracy at the city level. The method can also provide a good accuracy at a more fine-grained zip code resolution; for example, the estimation of the percentage of Asians yields a high correlation at zip code resolution for Seattle.

Gender Equality and Social Segregation

Demographic attributes of individuals have remarkable effects on their socioeconomic status, while traditional methods of individual profiling based on surveys and censuses are costly and follow a long-time delay. Recently, data from novel sources such as social media (SM) and mobile phones (MPs) have been used alternatively to predict individual demographic attributes and to analysis social and religious segregations. Moreover, individual behaviors on social networking platforms have been used to estimate individual personality and mental states such as depression and suicidal intent.

MP and online data have been used to infer demographic information – gender in particular. Frias-Martinez et al.[20] analyzed call detail records (CDRs) and found that male and female users are significantly different in behavioral and social variables such as duration of calls and degree in social networks. They proposed a semi-supervised classification algorithm that can identify gender with an accuracy up to 0.80. Felbo et al.[21] developed a convolutional network architecture to transform MP data into high-level features for each week and then aggregated patterns across weeks by reusing the same convolutional filters. They designed a 2-step model using an SVM with a radial basis function kernel, which slightly outperforms the state-of-the-art method, with an accuracy 0.797 in gender prediction. On the exposure of online platforms to different genders, Mislove et al.[22] inferred gender of Twitter users representing more than 1% of

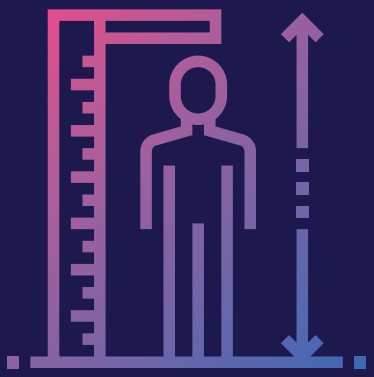
the U.S. population based on their first names and found that 71.8% of the users had a male name, showing a strong gender bias of Twitter towards male users. On the height premium in labor market, Yang et al.[23] found stronger effects of height premium on female than on male after analyzing a dataset covering over 140,000 Chinese job seekers. Of particular, they found that the gender differences decrease as the education level increases and become insignificant after holding all control variables fixed.

By leveraging novel large-scale data, urban segregation of people with different socioeconomic status have been studied. For example, Shelton et al.[24] developed an approach to study intra-neighborhood segregation, mobility and inequality based on geotagged tweets in Louisville. They proposed to understand Louisvillian neighborhoods by the fluid, porous, and actively produced. Similarly, Yip et al.[25] analyzed the mobility patterns of people in Hong Kong that are tracked by a mobile phone app. They found that the interactions of people with other income groups are limited. Rich people tend to move to rich neighborhoods, while poorer people tend to move to poorer neighborhoods. Recently, Louf and Barthelemy[26] provided a direct definition of residential segregation and showed that the richer class in high density zones is overrepresented. In particular, they suggested density as a relevant factor for understanding urban income structure and explaining differences observed in cities.

Data from social networks have been used to study religious segregation and urban indigenization. Hu et al.[27] quantified religious segregation by analyzing religious social network based on Weibo. They found that the religious network is highly segregated, and the extent of religious segregation is higher than racial segregation. In addition, 46.7% of cross-religion connections are probably related to charitable issues, suggesting the role of charitable activities in promoting cross-religion communications. Yang et al.[28] identified the distinct mobility patterns of natives and non-natives in five large cities in China by analyzing about 1.37 million check-ins. They found that the distribution of location visiting frequencies is relatively homogeneous for natives as they usually check in repeatedly at locations of personal importance. By contrast, the distribution is more heterogeneous for non-natives as they tend to visit popular locations. With this insight, Yang et al.[28] proposed a so-called indigenization coefficient to estimate the likelihood of an individual to be a native or to what extent an individual behaves like a native, which is based solely on check-in behaviors. Such method can be applied in estimating the time required for non-natives to behave the same as natives as well as in enhancing the prediction accuracy of human mobility.

Climate Action and Disaster Relief

Climate change and disaster surveillance is critical to social and economic systems. Along with increased urbanization and changing climate, many areas are now facing an unprecedented number of emergent events and natural disasters, which pose numerous threats to human life and economic development.



On the height premium in labor market, Yang et al found stronger effects of height premium on female than on male after analyzing a dataset covering over 140,000 Chinese job seekers

It urges rapid situational awareness and efficient management strategies to reduce human suffering and economic losses. In rural areas, assessments of natural hazards usually follow a delay, resulting in difficulties of disaster response and relief. In urban areas, detections of natural disasters (such as earthquakes, floods and hurricanes) are critical not only for governments' rapid disaster response but also for in-depth understanding of human behaviors in extreme situations that will help in better designing strategies in disaster relief.

Novel data sources have been leveraged to improve emergency awareness and disaster management such as remote sensing (RS), mobile phone (MP), and social media (SM), with remarkable advantages of low acquisition cost, real-time updates and high spatio-temporal resolutions. In particular, deep learning algorithms have been introduced to analyze RS data for rapid earthquake damage mapping. For the 2010 Haiti Earthquake, Cooner et al.[29] evaluated the effectiveness of several deep learning algorithms in detecting earthquake damage. They found that spatial texture and structure features extracted from satellite images can detect damaged buildings with an error rate below 40% under a multilayer feedforward neural network framework. Similarly, Bai et al.[30] developed a deep learning algorithm to map damage due to the 2011 Tohoku Earthquake-Tsunami. Their algorithm can classify damage with an overall accuracy 0.709 based on pre- and post-disaster images.

Rapid emergency detection based on mobile phone (MP) data can facilitate humanitarian response and reduce the toll of extreme events. Based on the combined data of MP activities and official event records in Rwanda, Dobra et al.[31] proposed an efficient system that can detect days with anomalous behavioral patterns under many emergent and non-emergent events. MP data have also been used to assess population displacements and improve emergency responses during large-scale disasters. For example, Lu et

al.[32] explored the predictability of population displacements after the Haiti earthquake. They found that the population in PaP decreases by 23% in the three-month period after the earthquake due to population movements. Also, the destinations of people who left PaP during the first three weeks correlate well with their mobility patterns during normal times.

Social media (SM) is a valuable source of information for gaining situational awareness, detecting and locating emergent events, improving disaster response, and enhancing relief efforts. Indeed, the utilization of SM data has transformed the methodology of earthquake detection and early warning[33], where the distribution of shakings can be mapped in minutes from earthquake-related posts. For example, Acar et al.[34] studied earthquake information sharing on Twitter by analyzing the tweets posted near two disaster-struck areas during the 2011 Tohoku Earthquake. They found that people in directly affected areas tweeted to announce their uncertain and unsafe situation, while people in remote areas tweeted to inform followers that they are safe. SM data have been increasingly used in monitoring and mapping floods in a timely manner. For example, Arthur et al.[35] leveraged tweets to detect and locate flood events in the UK. They collected tweets containing flood-related terms and located flood events by analyzing many indicators such as mentioned place names and GPS coordinates. They produced high-quality flood event maps based on the relevant geotagged tweets and validated the flood maps by official data.

SDG3: Good Health and Well-being

Ensuring the healthy lives and promoting well-being for all are the goals of the SDG3. With the coming of big data and the development economic, the last decade has made the significant strides in increasing the life expectancy and reducing the infant and maternal mortality rates. With the availability of various data sources, lots of data-driven model have been developed and major progresses have also made in preventing the spread of the communicable diseases, such as malaria, the seasonal influenza, and the pandemic, and so on.

A report given by the Centers for Disease Control and Prevention (CDC) shows that, an average of 28.41 million cases, 461 111 hospitalizations, and 40 500 influenza related deaths occur in each year from 2005 to 2018 in the United States,[36] which caused the economic burden at $5.8 billion annually. [37] As the globular head of hemagglutinin is evolving continually, the efficacy of the seasonal vaccines depends on the match between the antigens included in the vaccine and those presented by circulating influenza strains. Sah et al[38] assumed that if 10% of typical seasonal vaccines is replaced with 75% efficacious universal vaccine, according to the data-driven model accounted for various data monitored by the CDC, they showed that about 5.3 million cases, 81 000 hospitalizations, and 6300 influenza-related deaths per year would be averted. With the availability of the weekly temperature, relative

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humidity and atmospheric pressure data for each city of 603 cities in the United States, Dalziel et al[46] developed a climate-forced susceptible-exposed-infected-removed-susceptible compartmental model for influenza epidemics. They find that the period of the influenza season in the smaller cities is shorter, and the city-level incidence data is positively correlated with population size , and further their study reveal that the urban centers incubate critical chains of transmission outside of peak climatic conditions, altering the spatiotemporal geometry of herd immunity. For the understanding and prediction of the epidemic, Liu et al.[39] built a subset of the Italian and Dutch populations with the highly detailed sociodemographic data. By calibrating the epidemic model with the empirical epidemiological data, they show that the classical concept of the basic reproduction number is untenable in realistic populations. Litvinova et al.[40] performed a diary-based contact survey estimating the patterns of social interactions before and during the implementations of reactive school-closure strategies in the influenza season, and it is incorporated the macro sociodemographic data. With this innovative hybrid survey-modeling framework, they showed that the gradual reactive school-closure policies can mitigate the spread of influenza.

The emergence of the innovative infectious diseases, such as the SARS epidemic of 2003, the 2009 H1N1 influenza, and most recently the 2019_nCoV, affects the lives of tens of thousands or even millions of people. As the absence of the vaccine for the emergent infectious diseases and the globalization, the highly virulent innovative diseases increase the risk of every city in the world being invaded. Brockmann et al.[41] based on the air-traffic data defined the effective distance which predicts the disease arrival times of the invaded city accurately. Their method also works well for both the worldwide 2009 H1N1 influenza pandemic and 2003 SARS epidemic. Zhang et al.[42] developed a data-driven global stochastic epidemic model, accounted for the real-world demographic, human mobility, socioeconomic, temperature, and the vector density data, for the spread of the Zika virus (ZIKV) in the Americas. They estimate the time of first introduction of ZIKV to Brazil, and also revealed that the spreading features of ZIKV. For the new coronavirus originated in Wuhan, China, Chinazzi et al.[43] developed a detailed individual based mobility model which covers more than 3300 subpopulations in about 190 countries/territories. By using the cases detected outside China, they estimate the potential outbreak size in Wuhan and the basic production number. Similar to Chinazzi's report, by using the cases detected in overseas, Imai et al.[44] accorded to the traffic of Wuhan Interantion Airporte and estimate the basic reproduction number close to Chinazzi's. [43]

Visions and Actions

The availability of large-scale and high-resolution data from social and economic systems has provides a new way to improve urban spatial equity. For example, Louail et al. [45] analyzed a database of card transactions

in two Spanish cities and then proposed a bottom-up approach to redistribute money flows for equality situations through redirecting a limited fraction of individual shopping trips. They constructed the “individual-business” bipartite spatial network, where the edges correspond to card transactions. Then, they performed the rewiring of individual transactions by redirecting them to the same business category located in different neighborhoods. The goal was to re-balance the commercial income among neighborhoods and with the preservation of human mobility properties. They found that reassigning only 5% of individual transactions can reduce more than 80% spatial inequality between neighborhoods and can even improve other sustainability indicators like total distance traveled and spatial mixing. Their work illustrates an excellent implementation of crowdsourcing; the “Robin Hood effect”, a process through which capital is redistributed to reduce inequality.

Methods and data sources introduced in the Computational Socioeconomics can benefits the actions towards achieving SDGs and the evaluation of the progress. Specially, the above-mentioned novel perspective and methodology, driven by big data and artificial intelligence, will promisingly become the mainstream research framework in the action of SDGs.

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How to awaken the vitality of the city?

In an era of cities fully digitized, the definition for infrastructure refers to technology tools more than concretes and skyscrapers. Instead, it is a unified system of soft and hard integrated solutions and toolkits. The buildings, the streets and the whole city come to life. The language system and decision-making system for describing the city evolve accordingly. Citizens are able to witness the interaction and syntrophism of physical city and digital city. This is the Future City backed by the new round of urban infrastructure. Faster network connection, more accurate and personalized information services, autonomous-driving-designed roads coordinated by Cooperative Vehicle Infrastructure System (CVIS), circular ecological processing system, urban infrastructure strides across the obstacles of time and space.

The “joys and sorrows” of different periods of the city are stored in the digitally mirrored archive of the cities. The Data Middle Platform with spatial ID and human ID, as well as the Service Middle Platform that can be reused on a large scale, enabling urban operators to undertake large-scale data computation and resource coordination, thereby the infrastructure obtains the ability of evolution and iteration.

SECTION 2

DIGITAL TWIN CITY AND ADVANCING URBAN INFRASTRUCTURE

Your city is mirrored by a Digital Twin

Advanced Version 2.0 of Interactive City: Integrating Physical World and Digital World

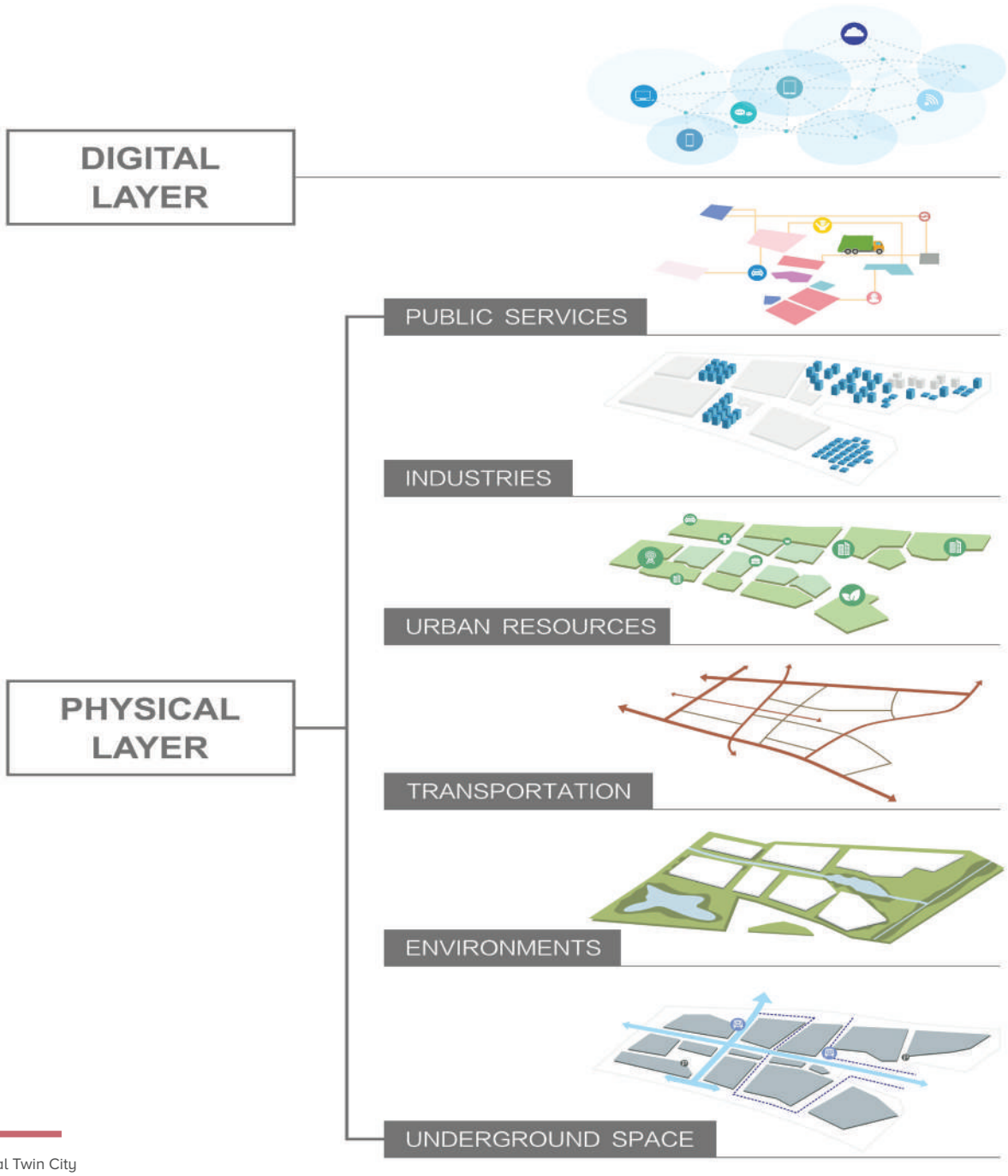
Hui Zeng, Lei Guo, Mingxiao Zhao, and Baolin Cao
WeBank AI
Institution of New Economic Development

In 1516, Thomas More's "Utopia", described an ideal and imaginary island country Utopia and highlighted the concept of a complete city from the passenger Raphael's perspective. In 1961, the classical work in urban planning, Jane Jacobs' "The Death and Life of Great American Cities," keenly captured the elements of the spirit behind the city, to creatively dissect the basic elements and their functions of urban structure. And then in 2018, the blockbuster, "The Number One Player" was brought to the fluorescent Screen, as long as people wear VR equipment, they can enter a virtual world where it is in striking contrast with reality.

Reality and imagination, technology and humanities, and human formulation about future cities exactly reflects the imprint of technology integrated into the era. In the era of industrial civilization, the image about cities is the infrastructure, such as highways and viaducts illustrated by reinforced concrete and various large centralized energy stations. However, evolving to the era of intelligence, new round of information infrastructure like 5G, the Internet of Things, and artificial intelligence takes the place. Cities are also exploring a new growing pattern, digital twins. Virtual cities and physical cities are mapped to each other and correlate in an orderly manner, growing into an iterable product soul through virtual-real interaction. This is similar as the sand table provided by JingAn Institute (Chinese-Vension Bureau of Investigation) in the series The Longest Day In Chang'An. Chang'An's 108 communities, 14 Streets from North to South, 11 Streets from East to West, curved lanes, and the ancient transport canal in the community are mapped on the sand table. Physical space and virtual space find a rhythm of the same rule.

Standing on the key stage of transformation, the physical skeleton and digital texture of the city are also experiencing tremendous changes.

Quayside, the "future community" designed by Google's Sidewalk Labs in Toronto, claims to create "the world's most powerful urban data management mechanism", and manages personal-ID-based data and urban physical-space-based data in the form of "Urban Data Trusts." Innovative applications are encouraged such as autonomous driving and intelligent waste processing chains. According to the analysis and forecast, the project will increase fiscal revenues to about



Digital Twin City
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$4.3 billion for different levels, contributing $ 14.2 billion to Canada's GDP each year and creating 44,000 long-term vacancies by 2040.

At the CES Las Vegas Consumer Electronics Show (CES) in 2020, Danish architecture studio BIG and Japan's Toyota Motor Corporation announced that they would build a "future city prototype-Woven City" based on wooden buildings and autonomous vehicles, which would be close to Mount Fuji in Japan. Woven City divides urban roads into three types to accommodate to different speeds, including highways for autonomous vehicles, low-speed road for personal travelling (bicycles, scooters, and Toyota's i-Walk), and sidewalks. There is also a network of underground pipes connecting directly to each building and home within the community. And more importantly, through interconnecting people, cars, buildings, streets, etc., it can be switched between the real-life field and the digital world, forging the test iterations of AI technology.

Back to the context of China, with the proliferation and large-scale commercialization of 5G technology and technology companies participating in the competition of the second half of urbanization, the low latency (the peak value jumps 30 times compared to 4G), large connection (supports 1 million sensors per square kilometer to connect to the Internet), high-speed motion support (supports data connection at 500 km/hour) and other advantageous conditions, the urban traffic and data will embrace an explosive boom from its birth. The progress of 2.0 version of the digital twin city has been triggered.

The Virtual World: Urban Operating System Built on Multidimensional Data

What is the fast lane or even the overtaking lane in the era of intelligence?

It is to establish the future city operating system based on the convergence of data and AI technology. There are threefold core tricks:

Firstly, to establish an assembling and processing mechanism for plurality of heterogeneous data sources via creating space-based ID. On the one hand, applying "from top to bettom" – from remote sensing image to different geographic information like location-based-service information and queries. On the other hand, to begin from the beginning, build a city-level City-Intelligent-Modeling (CIM) system. A Chinese proverb states, "Be familiar with astronomy and geography." Along with the liberalization of related policy about private use of satellite remote sensing since 2015, the cost of utilizing satellite remote imagery dropped significantly, and the accuracy improved dramatically. There comes the best time to apply spatio-temporal data analysis into practice, compromising High-frequency and low-frequency data. As a result, urban region turns out to be the hotbed of the implementation of large-scale AI computing capacity. Particularly, as China's first civilian sub-meter high resolution optical stereo mapping satellite - GF-7 has stepped into the application stage, the Earth gets an access to three-dimensional anaglyph for the first

Toyota Woven City
© **Toyota Woven City**

Through customized data, engine of logic rules, comprehensively connected digital guidelines and self-optimization model system, the system could achieve multi-disciplinary interaction and coordination as well as intelligent iteration

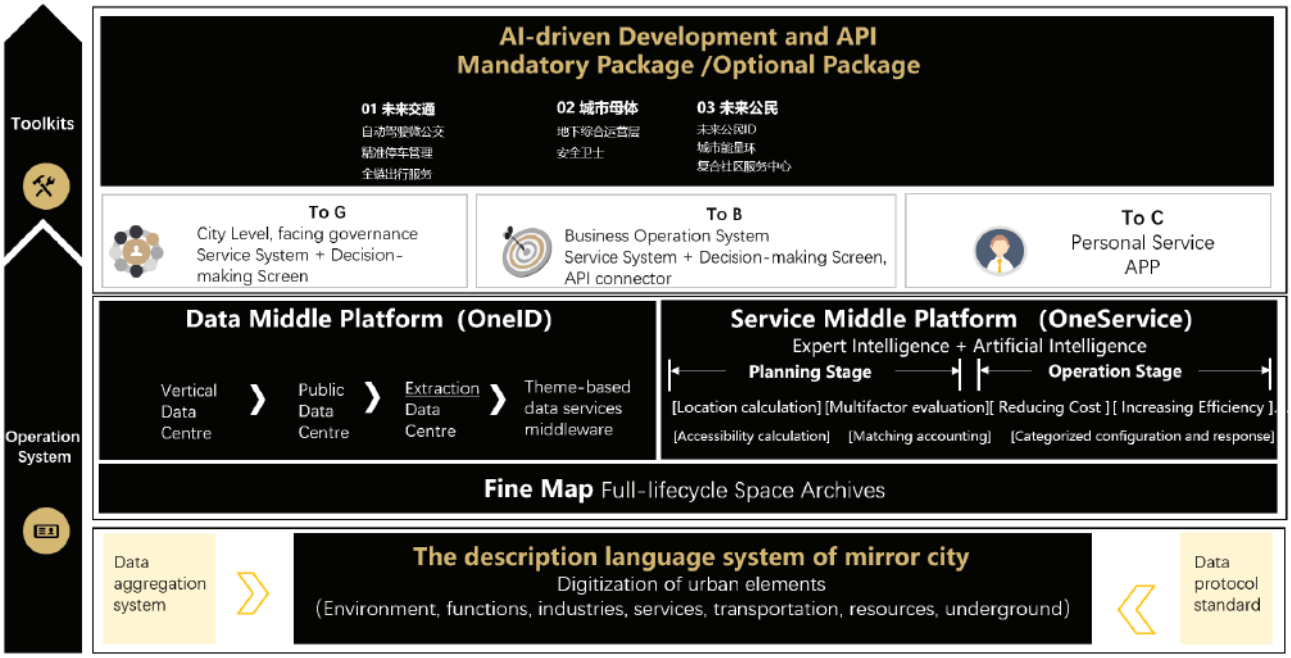
time. It is no longer a dream to compute city's "body measurements" based on aerospace integration. Observing the urban changes from million-feet-high in the sky produces vivid scenes, and this resolves the bottleneck problem of the research about geographic information data.

In addition, it is a benefit to establish a city-level CIM system covering the full cycle of planning, construction, and operation. Space-based ID system categorises the city into the smallest space unit, locating as the entrance of operation system and providing component-level position information. Each building and each street comes to life. Behind this, it requires to build an underlying platform with multi-tool integration based on GIS + BIM + IoT from planning stage. Through customized data, engine of logic rules, comprehensively connected digital guidelines and self-optimization model system, the system could achieve multi-disciplinary interaction and coordination as well as intelligent iteration. It enables multiple proposals' simulation, deduction, and comparison prior to the implementation of decision-making.

Secondly, it is to structure Data Middle Platform and Service Middle Platform which could be duplicated on a large scale. Through multi-module integrated sensors and edge computing terminals with high computing capacity, the capacity of city's analysis and decision-making are delegated to distributed terminals. It is like on-orbit calculations could be performed on satellites, and algorithms are carried on satellites, directly undertaking real-time data processing and analysis in space. Benefiting from better accuracy of data granularity with the time and space dimensions, the urban operator is able to obtain individual-based ID profiles with permission, such as the GPS records and searching data. After data masking, the situation of city or users could be tracked and forecasted at a higher level, linking lean management and more personalized, user-oriented service. Behind the recommendation algorithms for a thousand people with a thousand vension, ID portrait, crowd dissection, and crowd enlargement, answer the crucial three questions: "Who is he/she?"; "who are they"; and "Who is the same as them?". Similar perception of the Middle Platform could also find the targets in the urban field. The Data Middle Platform transfers the data from different sectors and sources to storage to integrate, to extract and to package as products, breaking down the barriers between data and eliminating the differences of data standard and caliber inconsistency.

It is followed by the overall digitalization of urban elements so that data could be relocated as urban resources for asset management. Furthermore, starting from the rules library and model library, Service Middle Platform revolves around the basic concept of "urban hydropower and coal", abstracting common capabilities and shared business modules, exporting public fundamental modules and shared service unit. At the application end, it combines the intelligent infrastructure from the physical space and packages varieties of solutions for various fields.

Thirdly, it is to construct an extensively empowered data opening and trading mechanism. Shanghai and Beijing have successively launched public data-opening policies, both of which proposed the



Urban Operation System
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establishment of a hierarchical classification data-opening mechanism and inventory list management mechanism and data-opening platform and ecosystem. There is no doubt that city becomes the most significant energy field generator for data production, processing and reuse. Therefore, it ought to establish a set of data mechanism serving for different kind of users, forming monitoring system for various urban space products like innovative furniture and spaces (automatic driving customized lanes) and bridging industry incubation and digital transaction. To make intelligent technologies step into real life, it's to create a 24/7 roadshow stage and trading platform.

The physical world: Circularly Sustainable Urban Base Layer

When it comes to physical cities, smart applications ought to be objective to the basic urban elements and serve for people's demands for a better life and high-quality community. After analyzing those quality-conscious cities globally, it is not that hard to answer to those shared pursuits including seamless and accurate smart travel, cycling low-carbon communities, vibrant mixed

Customized Road for Autonomous Driving
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functional units, warming ecological texture, healthy and sustainable underground bodies, flexible and responsive public spaces, etc.

Within the system, apart from the role as the tool, technology takes on more roles: catenating different sectors with humanism and the pursuit for arts as well as seizing the balance of overall system. Therefore, digital twin is not just moving the system to the cloud, building several engine-rooms, or undertaking visualization screen projects, it in fact calls for the consideration of full-cycle integration between digital city construction and the ascent of physical space (Planning-Construction-Operation), assimilating smart applications into urban context, soft tissues, and even the brain. For example, the requirements for the road system for full-spectrum autonomous city includes the stable design of pedestrian crossings, the charging system accommodating to renewable vehicles, and the fusion node design for different travel modes' intersection. Another example is that to achieve a distributed resource system and micro-circulation system consists of solid waste, water, and energy. What would be the best way to consider buildings, clusters, and regions at various levels? And how about the best proposal for energy balancing plan based on building-space-unit? Besides, how does one integrate inclusive and personalized hierarchical public services with communities owning 15-min walking accessibility, how does one bridge the gap between the iterability of technology and the adaptability of space; And, how does one achieve the modular organization and updates of architecture units through parametric design.

The coexistence between space and technological transition is a shared problem

facing designers and scientists. It exactly involves a series of technique selection analysis and trans-industrial landscape research for smart scenes. Behind this, it hides a series of integrated software and hardware solutions and toolkits.

Upon the virtual cities and physical cities, it waits for the business model for urban development and operation. Profits from land and real estate are no longer the unique revenue model. Physical city embraces better growing-up via operation and rental business, while digital revenues breaks traditional space-time constraint. Thanks to digital twin technology, cities contributes to a set of precise maps and spatial archives covering full-lifecycle of the city.

In the business-driven era, we developed Taobao, but in the technology-driven era, there also appears a new Taobao driven by urban innovation. In the forthcoming decades, the physical and virtual spaces of the city will undertake the role of displaying the platform for commodities (that is, urban services and applications).

The application of emerging technology from the laboratory to real society, such as autonomous driving, requires an adaptation process for the social system. It will be promoted and applied in lines with technology maturity, difference of regions and types. Through the landing-testing-evaluation-iteration mechanism of the digital twin, it enables enterprises to obtain data in time and to iterate the application, thereby promoting industrial agglomeration and urban Innovation.

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Interactive and Human-centered AI-Park
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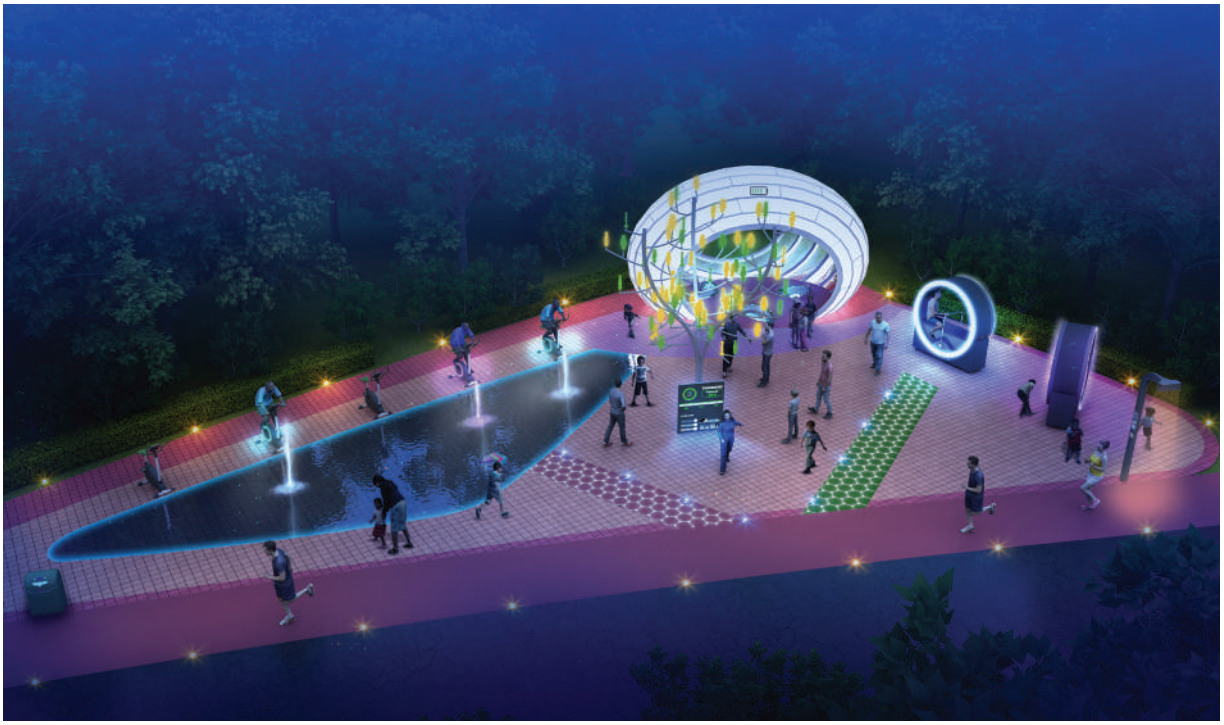


Every city has its own DNA

A localized smart solution is necessary for smart governance

Gerhard Schmitt
Singapore-ETH Centre

Future Cities and Governance

The first challenge is clear: within the next three decades, more than 2 billion additional people will need a place to live and work in existing and new cities, mainly in tropical and subtropical regions in Asia and Africa. Existing cities must be densified and expanded, new cities must be planned, designed, built, and managed. The second challenge is to decarbonize the energy production and thus to reduce greenhouse gas emissions and the urban heat island effect for these new types of settlements. They must be economically affordable, livable, nature-based, and regenerative to repair the damages caused by the rapid urbanization of the last decades.

These challenges cannot be met with just better infrastructure. Considering the novelty of having so many people concentrated in a given space, new types of smart and responsive governance are necessary. Since the beginning of human settlements, the successful cities has hinged on good governance. It "occurs when societal norms and practices empower and encourage people to take increasingly greater control over their own development in a manner that does not infringe upon the accepted rights of others".[1]

Smart cities and smart governance[2] are more recent developments. In smart cities, each component in the definition of good governance takes on a new meaning: Smart installations in cities will change societal norms; Information Technology can support urban governments and encourage people to take control of their urban development; and the accepted rights of others might change in light of the prevalence of stored data on each individual in a society.

Cities that focus on measures of good governance from the very beginning develop faster and better than those that are founded on and governed by one-dimensional goals. The access to sophisticated technology for every citizen, such as smart phones, is adding a new possibility for interaction between citizens and their governments, enabling smart governance.

Smart Cities

The term smart city has a relatively short history. It first came into broader use in the early 21st-century. The first phase of smart city initiatives often started with city governments buying technology directly from IT companies. By 2010, start-ups and more established companies alike were building products that provided quick solutions to specific urban

Smart Governance: digital twin Singapore, CIVAL and Kateryna Konieva, Big Data Informed Urban Design and Governance, © **Singapore-ETH Centre**

problems and selling them to individual departments within city governments. Large companies began to install more integrated smart systems in cities such as Songdo, Singapore, and Abu Dhabi. Citizens benefited from successful solutions, but also began to feel monitored, without exact knowledge of what would happen to the data collected. Today, Singapore, Zürich and Oslo lead the global Smart City Ranking.[3]

Forms of smart urban governance develop in a range between top-down and bottom-up. The reality of each city's governance lies somewhere in between. Daron Acemoglu and James Robinson have framed these characteristics slightly differently in their 2013 book "Why Nations Fail".[4] They refer to inclusiveness as the extent to which an institution grants people input in decision-making processes, while extractive institutions allow an elite to rule over and exploit others.

An early example of a smart city with a smart governance is Venice in Italy. The founders and people who made Venice a world power during the Middle Ages had limited land and built the city by ramming millions of trees into the soft ground. They developed a smart transportation system: Besides narrow streets, they relied on canals; instead of slow, horse-driven vehicles, they relied on wind powered sailing ships outside the city and on rowing boats that could dock directly in front of each house inside the city.

Though it obviously lacked digital devices, Venice was smart because it gained ample intelligence through international trade with surrounding countries and cultures. It recorded

and stored this information in extensive archives, making it available to future generations. It was also a partially responsive city: Every free man had the opportunity to rise to the top of the government and be involved in the governance of the city.

The city's most beautiful buildings came into existence during the height of the Republic. Acemoglu and Robinson connect the beginning of the decline of Venice as a global power to the so-called Serrata[5] or closure: the decision in 1297 by the Great Council to seal the government off from people outside the nobility. This shift from an inclusive to an increasingly extractive system did not immediately destroy the city, but slowly suffocated its further technological and intellectual growth.

We can learn from this historic example for urban governance. Inclusion is probably the most important factor for longevity, sustainability, and resilience of human settlements. Inclusive and smart governance is also a strong factor in livability rankings of cities around the world. Highly livable cities all have an inclusive and smart governance structure. In addition, perhaps as a result, the inequality of income and wealth distribution in these cities is relatively low, as measured by the Gini index[6] that describes the inequality among values of the income distribution.

The Future Cities Laboratory – from Smart to Responsive and Regenerative

The ETH Future Cities Laboratory at the Singapore – ETH Centre[7] is located in the smart nation Singapore and in the responsive city Zürich. Its motto is designing regenerative future cities through science, by design, in space and time. One of the major findings is that future cities need citizen-centered governance, evolving from smart cities into regenerative and responsive cities with responsive governance. Smart cities have made investments in technology, both from the side of the city and from the side of the citizens. Building on this, cities can now place human needs and interactions at the center of their development. In this way, cities become more responsive. Data in a responsive city come from smart buildings, smart infrastructure, and, most importantly, from smart citizens.

In the responsive city,[8] the inhabitant will change from being the subject of observation to become an active partner in the governance of the city. Smart city technology will enable the individual citizen and community of citizens to plan, build, and govern more sustainable, resilient, and regenerative cities. At first, this may sound like an impossible vision: how could it be possible that lay people can contribute to the advancement of the city when sophisticated approaches to governing have been refined over centuries? Yet evidence suggests a different story. There are urban systems, cities, and villages that

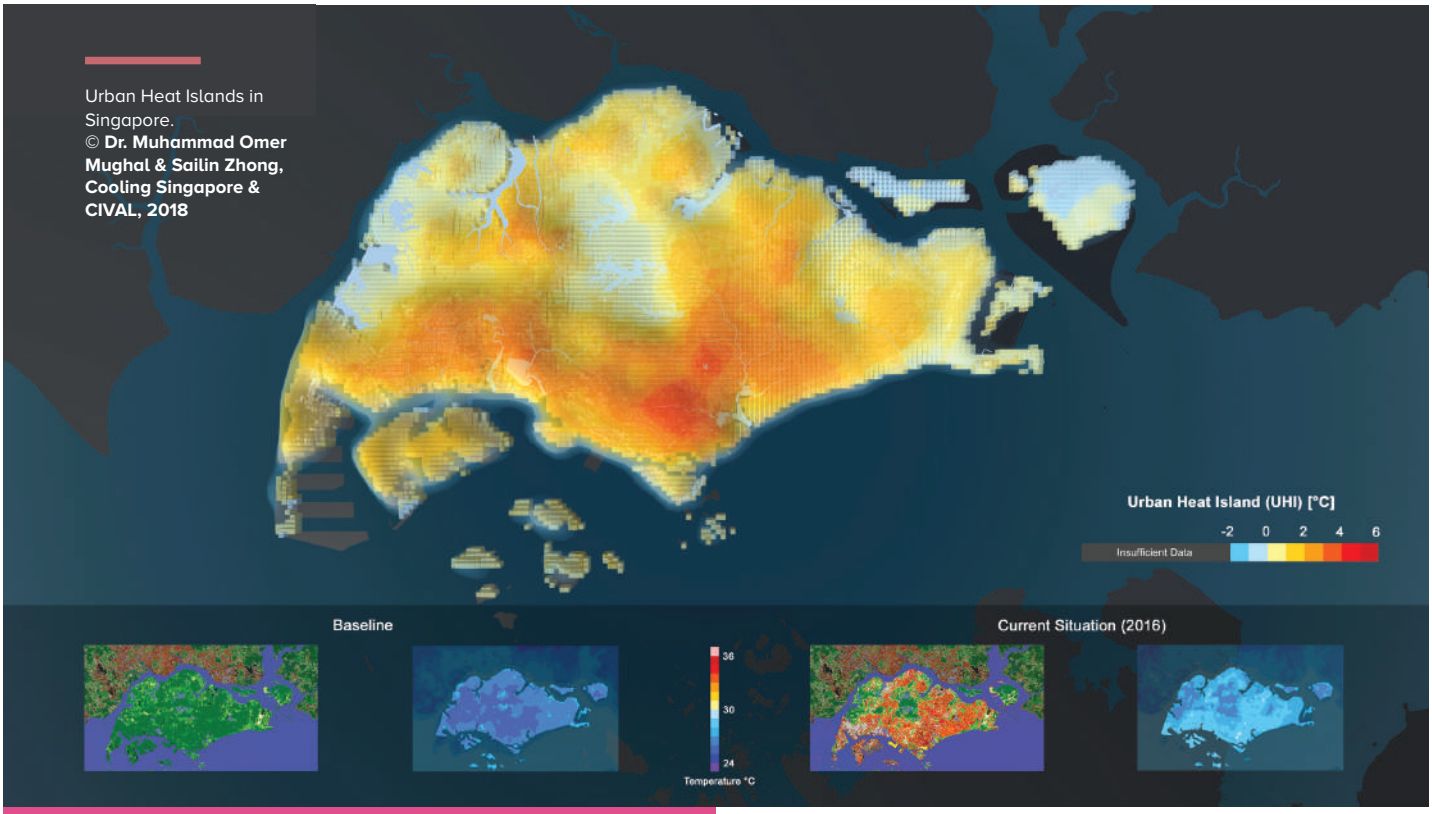
© Pixabay/Lukas Vitt

already live in a responsive and regenerative way. They combine high-tech and high-social skills. They share a strong sense of community and respect towards their fellow citizens and towards the environment, and they follow an inclusive, corruption free, and fearless path.

Example Vauban

An early example is the Vauban district in the city of Freiburg, Germany. Located on the site of a former military complex, the new district developed bottom-up after its military use ended, totally changing its original character. The new citizens, mostly families with children, aimed towards shared values. One of them was sustainability, and out of this followed the quest for buildings that produce more energy over the course of their life than they actually consume, a step towards a regenerative settlement. Instead of the normal transportation planning, centered on private transportation and cars, the walkability of the new district became the focus of attention: The use of cars is not forbidden, but quite reduced, creating a pleasant atmosphere. Car-lite, as it is now called in Singapore. More importantly, the citizens were actively involved in the planning, construction, and management processes. Vauban demonstrates that it is possible to combine a high-tech approach with sustainability and resilience, laying the foundations for regenerative cities. It could be a model for larger settlements and eventually for entire cities. Citizen engagement is a defining quality of Vauban, and the project is an early practical instance of citizen design science.[9]

Cities become first smart and then responsive and regenerative. What differentiates the responsive city from the smart city is its dynamic, interactive behavior. Responsive cities build on smart city technology, but place the human, specifically the engaged citizen, in the center of the planning, design, management, and day-to-day decision-making of the city: its governance. The boundary between the smart city with smart governance and the responsive city with responsive governance is not a sharp line but, rather, a range of possibilities that apply both to urban systems and rural systems, essentially to the entire human settlement system. The responsive city is citizen centered – it will give the city back to its citizens.



Urban Heat Islands in Singapore.
© Dr. Muhammad Omer Mughal & Sailin Zhong, Cooling Singapore & CIVAL, 2018

This has a major impact on governance, as in Switzerland the individuals have a strong personal leverage in mitigation, whereas in Singapore industry and government have a stronger leverage. Thus, smart governance needs to be organized differently in every city.

Governance, Climate Change and the Urban Heat Island Effect

One of the major challenges for the governance of future cities is the combination of climate change and the local urban heat island[10] effect. The Singapore – ETH Centre proposes solutions to this phenomenon that is increasingly damaging to tropical and subtropical settlements.

Depending on geographic location, its energy supply, its infrastructure, and its materials and surfaces, every city can become a heat sink or a heat island as compared to its surrounding temperature conditions. We differentiate between active anthropogenic heat sources such as transportation, industry, air conditioning systems, and passive anthropogenic heat sources such as streets, building structures, and other massive infrastructure.

Depending on the governance of a city, the individual citizen can contribute more or less to the mitigation of the urban heat island. In Switzerland for example, the citizens are responsible for two thirds of the heat emissions through their choices for cars and buildings, while industry is responsible for less than 20%. In Singapore, on the other hand, the individual citizen is responsible for less than 20%, while commercial buildings, transportation, and industry dominate the heat release into the urban system. This has a major impact on governance, as in Switzerland the individuals have a strong personal leverage in mitigation, whereas in Singapore industry and government have a stronger leverage. Thus, smart governance needs to be organized differently in every city.

Smart and responsive governance are necessary to mitigate and adapt to the rising threats of the combination of climate change and urban heat island effect. Thinking only for themselves, cities will first hurt their own citizens and contribute to climate change through excessive emissions. Taking a regional and global approach instead, cities will bring immediate benefits for their own population and for the global community. Therefore, for each city we propose a digital urban climate twin and a new governance body to host the urban climate management system that every future city will need. Thus, we recommend the move from urban design towards regenerative urban climate design. For this, smart and responsive governance is a condition.

Most text and examples are taken from Schmitt, Gerhard, Estefania Tapias, and Marta H Wisniewska. City in Your Hands. Apple Books, 2019. https://books.apple.com/ch/book/city-in-your-hands/id1451584143

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Cities are not only for the rich

Developing future cities for all: The necessary learnings for inclusive, future infrastructures

Jaideep Gupte
Institute of Development Studies (IDS)
Global Challenges Research Fund (GCRF), UKRI

Cities do not just happen. They are located in a historical context and in an increasingly complex global policy environment. The movement of people into, out of, and within cities is connected to the economic promise of cities, but it also determines the nature of the built-environment. Similarly, urban infrastructure is a multifaceted concept that goes beyond a set of engineered facilities, utilities, and systems. All this means that the grand infrastructural challenges of the future are not simply technical or construction related. At their heart, these challenges are also political in nature. They lend themselves to varied entry points, and they require action by multiple stakeholders who may share a general commitment to the values and principles of the Sustainable Development Goals (SDGs), but may not agree on priorities or emphasis. In this essay, I offer perspectives on the infrastructural challenges of future cities through three entry points: the intersection of the built-environment and marginalisation; digital infrastructures; and infrastructural decisions for climate change mitigation and building resilience.

The intersection of the built-environment and marginalisation

Investment into and the development of the built environment implies inevitable changes and political turmoil between the winners and losers. As such, advancing urban development demands addressing complex questions that interrogate the relationships between power, politics, materiality, and urban engineering:

- Who are the most marginalised?
- How do we understand their everyday interactions with infrastructure?
- How do we measure who is thriving, just surviving, or failing in cities?
- What actions, actors, and technologies should be prioritised to reduce infrastructural exclusions?

Critical evidence shows us that human-infrastructure interactions are gendered, unequal, segregated, and racialized. Over time, inequality gets locked into spatial

Infrastructural interventions can perpetuate inequality. In Mumbai, India, informal settlements continue to co-exist with publicly provided social housing. © **Jaideep Gupte**

forms and institutional systems in cities – but also underneath them – in the labyrinth of buried infrastructures in the subsurface. The assembling and choreography of cities through the myriad techniques, routines, standards, and visions of engineers is inextricably bound up with broader socio-cultural, material, and political urban dynamics and processes.[1] This positions networked infrastructure at the heart of what describes the city as 'modern'. It also describes infrastructure as in constant state of flux, as constitutive of social relations of inequality, and in a proximal relationship with environmental transformations.[2]

However, the configurations of agency which shape urban infrastructures are power-laden not because they exclude subaltern people but, importantly, because the local actions of at-risk and vulnerable groups are themselves constitutive of innovation and urban transformations. We have seen how vulnerable and least-resourced women and men have organised themselves in pursuit of secure shelter in cities like Mumbai, where those who lack secure shelter are conspicuously absent in the design and execution of development plans. Invariably, city planning and real-estate markets produce solutions that exclude the poor, and limited city resources are quickly absorbed by the shelter demands of less needy groups. In these circumstances, social movements of the urban poor will continue to have a role to play in "creating a common language to bridge the gap between this formal world and the communities presently trapped in informality, and in developing new systems to engage these most central stakeholders who are not currently viewed as part of the solution."[3]

Digital infrastructures and institutional change

Smart city initiatives play a prominent role in international development interventions involving legislation, land-use, and data governance across the global south. Promoting technological solutions that enable inclusive data driven urban governance is therefore vital. While there are a variety of local expressions of 'smartness,' the dominant rationale for smartening up urban development is that doing so can trigger economic growth, and therefore be a route out of poverty. However, there continues to be a fundamental gap between the types of technological solutions being proposed to enable data driven urban governance, and whether these solutions, and the manner in which they are being implemented are necessarily promoting inclusivity, resilience, and sustainability.

One perceived drawback has been the lack of reflexivity across experiences in the Global South, particularly those of economically and socially disadvantaged urban residents.[4] The smart city discourse has tended to be driven largely by ideas and experiences rooted in the global north, while evidence from developing country contexts, including instances of South-South learning, have not been brought into focus. There is sparse documented evidence from urban Africa on, for example, how data infrastructures should be governed, as the literature is almost entirely comprised of evidence on regulatory compliance. This lack of rigorous evidence-based academic scrutiny of data governance in developing

To be truly transformative, cities need to take notice of the organisational and institutional changes required by new technological innovations and a shift towards data-based governance, at the same time as maintaining the ethical and democratic grounds on which digital infrastructures are built.

country contexts implies a stifling of systems of learning and innovation, which invariably leaves digital infrastructure vulnerable to threats arising from local (context specific) risks.

To be truly transformative, cities need to take notice of the organisational and institutional changes required by new technological innovations and a shift towards data-based governance, at the same time as maintaining the ethical and democratic grounds on which digital infrastructures are built. This is not straightforward. It implies a gruelling level of complexity, and the need for gutsy decision making on the part of the policymaker to find ways forward.

Infrastructural decision making for climate sensitive building

By 2050, an estimated 68% of the world's population will live in towns and cities. The majority will live in small and medium-sized urban centres in Africa and Asia, where most of the urban infrastructure required to accommodate the urban population of the future is yet to be built. This presents an opportunity for intergovernmental efforts to tackle climate change under the United Nations Framework Convention on Climate Change (UNFCCC) and the Sendai Framework to firm up commitments at all levels – global, national, and local.

And at all these levels, governance is comprised of layers of contested authority, formal and informal, that have accreted over time without alignment or co-ordination. Nevertheless, future infrastructural decisions, both political and material, offer an opportunity to reset the power dynamics to allow successful delivery of sustainable urbanisation.

In response, cities across the world are showing up to the table as willing participants to drive transformational change. C40's Climate Action Planning is sending out a strong signal to citizens, economic operators, and members of civil society by setting the goal of achieving carbon neutrality by 2050 and by defining the transition towards a more environmentally and climate-friendly way of life as a universally shared vision.[5] The call is to make fundamental changes to the everyday mundane functioning of cities: including how we design, install, and maintain the pipes, wires, drains, tarmac, tracks, bridges, and buildings incorporating affordable, low-carbon building techniques that are resilient to climate change and supporting the equitable and sustainable provision of basic services. Importantly, this requires a total reorientation of economies around clean energy to transform the way people get their electricity, heat their homes, and commute to work.

As much as these are socio-political transformations, analytical and empirical attention on the role of city engineers in the production, contestation, and mediation of the built-environment remains central. Far from being 'arcane' to urban transformations, engineering is "a diagnostic for probing the shifting forms of mediation that animate and inhabit contemporary dynamics of urban socio-spatial transformation and material contestation."[6] At one level, something as seemingly straightforward as introducing new climate-sensitive materials to the construction process is in practice a deeply complex negotiation between technological innovation, market dynamics, and city specific processes of production. At another level, smart city imaginaries are themselves recalibrating the role and boundaries of urban engineering. Ultimately, if urban infrastructure is to be sustainable, the built-environment it supports also needs to promote an aspirational way of life, where living standards, quality of life, and wellbeing are improved for all urban residents.

In low- and middle-income countries, the real challenge is to balance infrastructural decisions such that they address the significant challenges of urban poverty and inequality, while also being climate sensitive. Kenya and India offer two examples where the governments have taken bold steps towards meeting the extreme deficits in affordable homes across their major cities and towns. In Kenya, the government has committed to building half a million affordable homes as part of President Kenyata's 'Big Four Agenda'. In India, the Pradhan Mantri Awas Yojana (PMAY) scheme for affordable housing sets a target of building ten million homes by 2022.

The scale of these initiatives brings their climate credentials and longer-term resilience into focus. The opportunity here is to view affordable housing as a complex challenge, not simply met by building more homes. Integrating critical infrastructure for energy,

Pump rooms at the Lallubhai Compound, Mumbai, India where pavement and slum dwellers have been relocated into publicly provided tenement blocks, only operate for a few minutes per day due to a severe shortage of piped water.

water and sewerage, alongside access to essential services like schools and health clinics, while resolving the constraints of where the building material will be extracted from, and the net-carbon impact of buildings made predominantly with concrete, require a complex systems approach to neighbourhood-, city-, and national-planning.

Conclusion: learning from each other to strengthen capacities

The three entry points to the infrastructural challenges of the future employed in this essay sit alongside several other equally important vantages (for example, from the point of view of financing green infrastructure, or building resilience towards multiple hazards and disasters). And yet even in their artificially imposed isolation, the three entry points present an agenda monumental in scale. As such, we must not simply shirk our responsibilities in hope that urban local authorities will somehow pick up the slack. Our collective effort needs to focus on strengthening the technical and institutional capacities of urban local authorities in three areas:

In low- and middle-income countries, the real challenge is to balance infrastructural decisions such that they address the significant challenges of urban poverty and inequality, while also being climate sensitive.

Kenya and India offer two examples where the governments have taken bold steps towards meeting the extreme deficits in affordable homes across their major cities and towns

- Local consensus building: support local authorities and citizens to come to an agreement about it means to be a ‘smart city’; which new technologies and types of infrastructure will be pursued; and how will important issues relating to both ‘hard’ and ‘soft’ infrastructure, around data security, ownership, privacy, and accessibility – particularly from the point of view of economically and socially disadvantaged groups in the city – be negotiated.

- Implementation: strengthen local capacities to involve vulnerable groups in the design of resilient and sustainable urban infrastructure, as well as in the identification, assessment and monitoring of exposure to multiple hazards and risks related to climate change.

- Equitable partnerships: strengthen equitable partnerships between urban practitioners, researchers, and civil society, at the city-level as well as between cities. It is as important to learn from failures, as it is to scale up successful innovation. However, the dual challenge of finding and implementing innovative technological solutions as well as effective, innovative, institutional solutions must be addressed in tandem, and in ways that are locally relevant.

Empowering local authorities to tackle the infrastructural challenges of the future is possible. Understanding and navigating within this type of complexity requires interdisciplinarity – the natural, physical, and social sciences need to come together with the arts and humanities, but in ways that are actionable and legible to local change makers

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Can we monetize and *cryptify* our garbage?

The case of mobile technology and community inclusion cryptocurrencies for PET recycling

Saiful Ridwan , Harrison Simotwo , Pietro Visetti
United Nations Environment Programme (UNEP)

Plastic waste is now so ubiquitous in the natural environment that scientists have even suggested it could serve as a geological indicator of the Anthropocene era. Researchers estimate that more than 8.3 billion tons of plastic has been produced since the early 1950s. About 60% of that plastic has ended up in either a landfill or the natural environment .[1] Our oceans have been used as a dumping ground, choking marine life and transforming some marine areas into a plastic soup. Cities are the largest sources of marine litter. Globally, 2 billion tons of municipal waste was generated in 2017 of which 240 million tons are plastic waste, 12% of the global municipal solid waste generation.[2] In cities around the world, plastic waste clogs drains, causing floods and breeding disease. If current trends continue, our oceans could contain more plastic than fish by 2050.[3] Not only is there the need to slow the flow of plastic at its source, but we also need to improve the way we manage our plastic waste.

Polyethylene Terephtalate (PET) is a type of Thermoplastic which follows under the category of single use plastics; which are all plastics intended to be used only once before they are thrown away or recycled. PET is mainly used for the production of bottles for water and other drinks, dispensing containers for cleaning fluids, biscuit trays and other packaging. Cheap, light, and modulable into myriad shapes, plastic bottles have conquered the world. Unfortunately, they have also become the kings of trash, accumulating at a mind-boggling rate to create one of the biggest pollution headaches of the current age. As the economic and environmental cost of this waste dawns on the planet, the quest for a solution is intensifying.

In Kenya PET consumption statistics vary and are difficult to verify. The Environment Ministry suggests that there are 50 million plastic bottles used annually in Kenya.[5] Academic research completed in 2008 indicated 160 million PET water bottles being used.[6] Ipsos estimates, based on packaging statistics, indicate that there were more than 725 million PET bottles used for water and other soft drinks packaging in 2017.

Latest (March 2018) statistics on plastic packaging indicated that plastic packaging (which results in plastic packaging waste) in

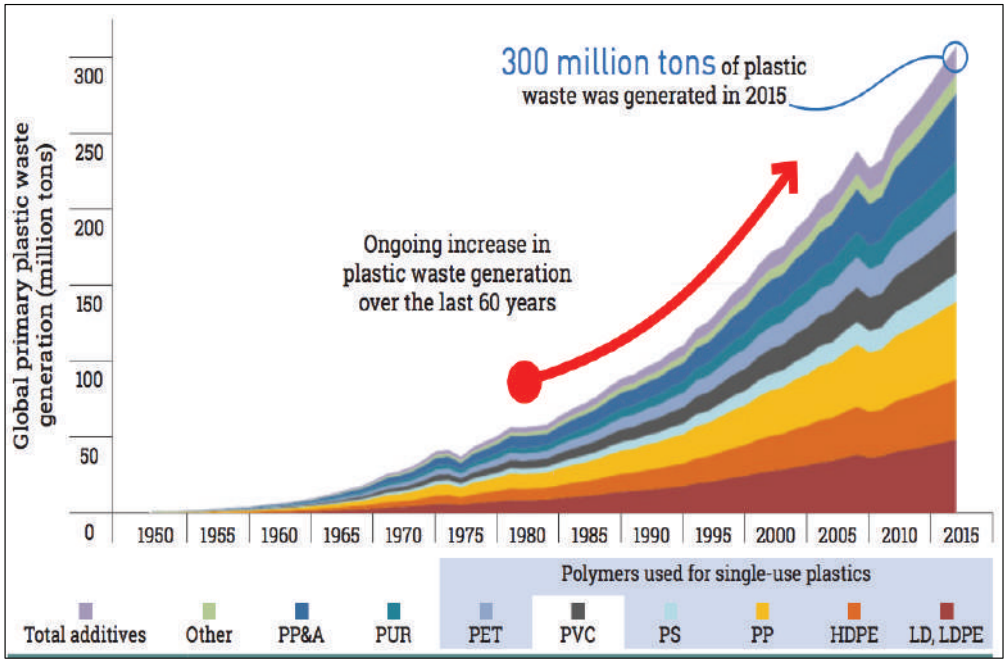


Figure 1 | Global primary plastics waste generation, 1950 – 2015
© **Adapted from Geyer, Jambeck, and Law, 2017**[4]

Kenya was approximately 260,000 tons.[7] Of this, 18% is estimated to be collected for recycling, with a total of approximately 15% recycled. It is estimated that 5,778 tons of PET plastic is recycled per year. Estimates for PET recycling rate may be as low as 13% (based on Ipsos calculations), indicating a significant opportunity for PET recycling.

Currently in Nairobi, there is no institutionalized knowledge on where PET plastic collection points are located and no official, publicly available recording mechanism for import, export, and recycling volumes. According to the Kenyan Association of Manufacturers (KAM), there are 39 major recyclers of which 11 are licensed by the National Environment Management Authority (NEMA). However, according to the Kenyan PET Recycling Company association, there are 5 existing PET collection points in Nairobi, which are clearly not enough to respond to the needs of a 4 million citizen city.

The problem is that Kenya does not have an organized waste collection. Plastic bottles lie along the roads and choke the stinking river that uncoils through the smog of the downtown high-rises. They float through open drains of sunbaked slums and shards pierce the bellies of flamingos and turtles.[8] Researchers warn that industry-led schemes are inadequate unless laws compel manufacturers to take responsibility for the waste they produce. Due to the poor institutional infrastructure it is hard to establish return schemes such as Extended Producer Responsibility. Patchy data is one of the key challenges that limits opportunities for improvement of plastics management.

BOX 1

Extended Producer Responsibility

In several developed and developing countries, the introduction of Extended Producer Responsibility (EPR) and deposit-return schemes[9] have proven effective in reducing littering from PET bottles while boosting the recycling sector. Deposit-return schemes involve consumers paying a small extra fee (5 cents are common in the United States) every time they buy a particular type of product. They get the money back when they bring the empty containers to a collection point (often a "reverse vending machine" positioned in a supermarket).

Germany, Japan and South Africa are among many successful examples where the responsibility for recycling used PET bottles is embraced by manufacturers (either voluntarily or by act of law).

The initiative introduced by the PET Recycling Company (PETCO)[10] in South Africa, for instance, shows how the introduction of EPR (even when voluntary) can help develop local end-use markets for recycling. In South Africa EPR has created jobs and business opportunities, while addressing one kind of problematic single-use plastics. While some other African countries are now starting to consider banning PET bottles, the South African example shows what can be achieved if due consideration is given to the socio-economic context and the most appropriate policy instrument (not necessarily banning) is selected.

Data, including geolocation data, transactions, and analytics can provide an improved evidence-base for policymakers to draft strong policy recommendations and develop forwarding looking scenarios. Digital communities have proven to be a reliable source of data gathering.

Novel technologies offer tremendous opportunities for citizen science, local engagement, and public participation for monitoring and behavioural change. Importantly, there can be a multidirectional exchange of data between scientists, citizens, governments, and companies.

UNEP in collaboration with PETCO Kenya, KAM, and Coca Cola is building a digital ecosystem to monitor the PET supply-chain from production to end consumer while creating a circular model for recycling plastic. The tech solution will crowdsource data on PET plastic by using a mobile app and will also incentivize citizens to recycle thanks to a reward mechanism powered by blockchain. The data collected across the PET value chain will be analyzed with Artificial Intelligence (AI) statistical models to feed an informative dashboard for citizen science and policy makers. The app will be the number one source to organically mine data from any stakeholder present in the Kenyan PET industry (Figure 2). However, to better capture and nudge recycling, the ecosystem will be completed with a futuristic application of cryptonomics.

PET bottle producers plastic companies which produce PET bottles in Kenya.

Beverage producers beverage company that using single-use PET bottle to pack their products including the imported ones from aboard.

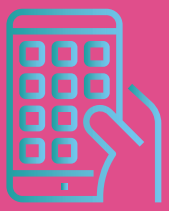
Retails shops including different size of shops, as well as bars, restaurants, clubs, school and hotels.

Recycling plants plants turn plastic waste into products

Collection points collection station, door-to-door collection organization which don't have the capacity to recycle PET bottles, but only serve as a primary collector in this chain.

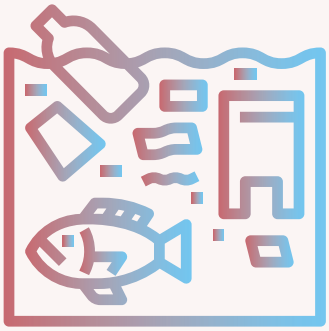
Consumer individual who is the ultimate user of the PET bottles.

Figure 2 | Simplified visualisation of data mining architecture for PET plastic supply-chain.



The tech solution will crowdsource data on PET plastic by using a mobile app and will also incentivize citizens to recycle thanks to a reward mechanism powered by blockchain.

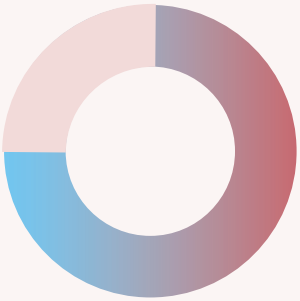
African facts & numbers
© UNEP, 2018



80% of marine plastic pollution comes from land-based activities

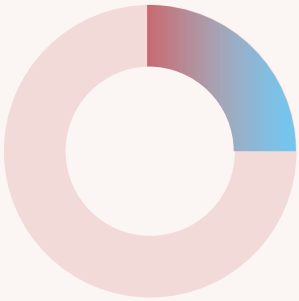
10.5 million tons

of plastic waste accumulation forecasted in Africa by 2025



75%

of all uncollected waste in Africa is plastic



25%

of the collected plastic leaks back to environment

To best capitalize the significance of the established digital ecosystem, an analytical and strategic dashboard is the natural end product of the PET data driven environment. To transform data into accessible real time information, AI and Machine Learning (ML) are deployed to show trends, bottlenecks, and projections. Dynamic and interactive, the dashboard not only is the starting point for policy making but it is also a transparent and more accessible tool to inform citizens on important public issues.

However, using markets as a way of alleviating plastic pollution and empowering people to be rewarded for sustainable actions is the key for organically collect data. Restructuring economies away from a neoliberal system in order to slow plastic pollution and respond to collapsing natural systems means introducing innovative solutions and tight government regulations. Policy instruments can either put a high cost on pollution and oblige polluters to pay for the environmental fallout or find system approaches that can help reverse

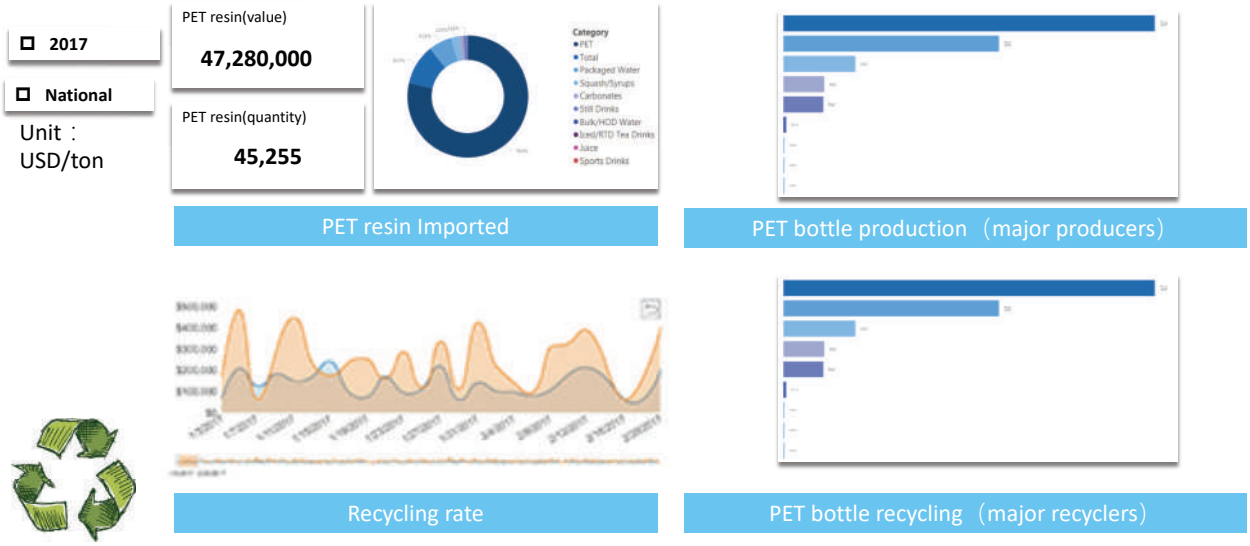


Figure 3 | Illustration of PET dashboard.

the paradigm and close the pollution loop. Digital technologies can support sustainability in a number of ways. Thousands of digital applications now exist for optimizing resource efficiency.

When companies extract oil and sell plastic, they earn money. When citizens recycle plastic, they are creating value, but normally they won't get paid. Our economy is out of balance. Part of moving to an ecological civilization, means looking to other ways of exchanging value. The low-regulation environment of neoliberal economics has allowed for plastic pollution to be dumped into the environment free of charge and externalized the environmental and health costs of producing this waste. This debt is now being paid in the form of marine litter, food and water pollution, biodiversity loss, and at large climate change.

In Kenya, plastic recycling centers are buying PET plastic at 12-15 Kenyan Shillings (KES) per KG. However, not many citizens are engaging in this practice as collection points are few, inconvenient, and the economic benefit is little. To overcome this issue UNEP will pilot a blockchain based Community Inclusion Currency (CIC) to create a profitable marketplace for PET plastic recycling in Nairobi. By linking PET plastic collection to a local CIC reward system, UNEP can influence citizens to recycle in a profitable way. In other words, the program will indirectly pay people for collecting plastic waste with a local currency which can be spent locally in exchange for goods or KES equivalent.

BOX 2

Community Inclusion Currencies (CICs)

Community Inclusion Currencies seek to enable communities to develop a source of local credit based on productive capacity and local values, creating a monetary system better suited to eradicate poverty. Community Inclusion Currencies are vouchers that community members use to buy and sell basic needs in the face of scarce national currency. CICs are backed by the local goods and services produced by a community.

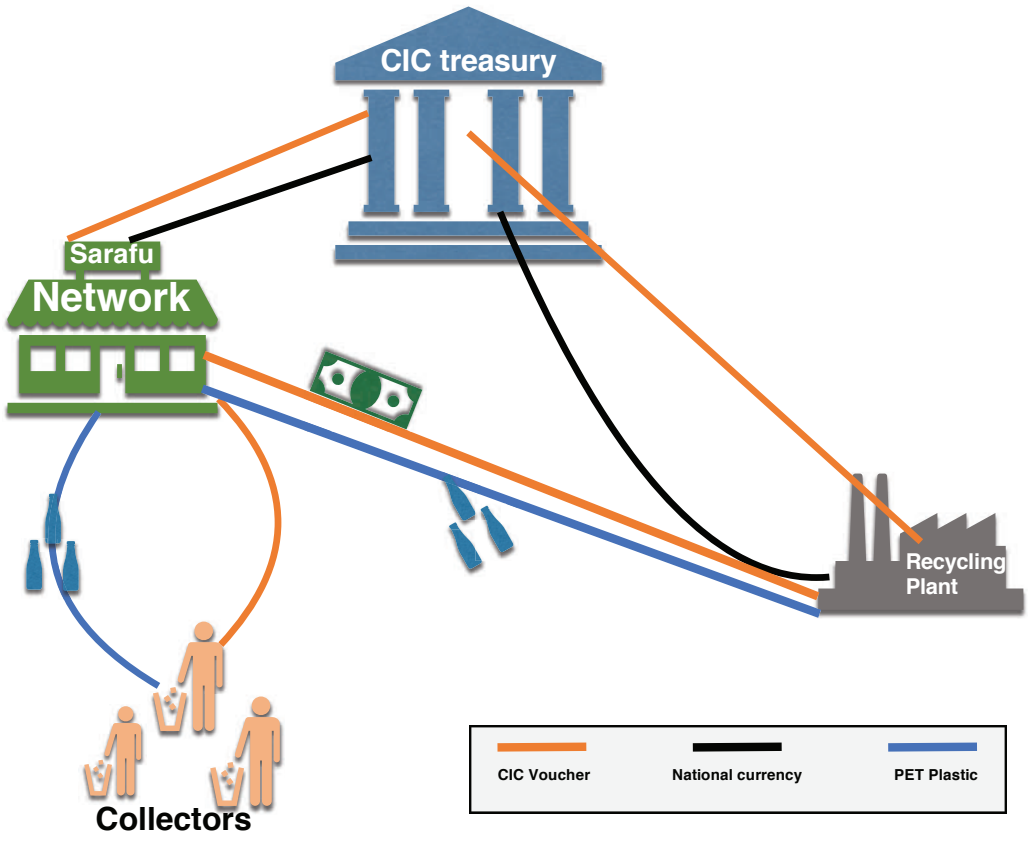


Figure 4 | Simplified visualisation of PET-CIC market.

BOX 3

Blockchain

Introduced in 2009, blockchain technology was initially used to serve as the public transaction ledger of the cryptocurrency Bitcoin. Blockchain is a Decentralized Ledger Technology (DLT) system that creates a cryptographically secure and immutable record system of any transaction of value, whether it be money, goods, property, work or votes. Thanks to the decentralization of the blockchain and the way it operates through several connected servers in a network, there is more transparency and security in all the value chains supported by the digital ledger, allowing a more efficient interconnection and information exchange.

For instance, Plastic Bank is a social enterprise which pays people for collecting plastic waste in Haiti, Indonesia, and in the Philippines. Individuals bring collected plastic waste to Plastic Bank[11] recycling collection centers where the plastic waste is exchanged for goods or blockchain secured digital tokens.

In Kenya, the Grassroots Economics Foundation[12] developed the Sarafu Network which is an ecosystem of blockchain tracked CICs in informal settlements. Thanks to CICs Grassroots has helped more than 8000 users improve their livelihoods and have better access to credit. Beneficiaries of their programs include small businesses and people living in informal settlements as well as rural areas.

Impact tokenization using blockchain is being established as a standard in the industry of international development. UNEP will launch and coordinate a pay-for-PET program in collaboration with the Grassroots Economics Foundation and co-create a network of social businesses that will purchase PET plastic with community currency. The Sarafu network already holds the critical capacity to kickstart the project in its communities by providing businesses with an additional source of income – namely PET plastic collection.

Blockchain can power smart contracts which are self-executing contracts with the terms of the agreement between buyer and seller being directly written into lines of code. A smart contract is not just a piece of code; it is a representation of business logic.

Figure 4 visually represent the PET token economy. Collectors sell PET plastic trash in community businesses and receive community currency which enables them to buy goods and services in the community. This is a new way to track, measure and reward sustainability so that now citizens can do good and get paid. Businesses act as collection points for recycling plants and sell plastic to them in return of community currency. Recycling plants invest in community currency in order to buy raw material for their production (alias PET plastic).

Recycling plants joining the PET CIC market will benefit from having consistent inflow of raw material at a lower market price. This is due to the fact that when recycling plants, as other participants, enter the CIC network, the KES they bring in has a four-time value multiplier against the network currency. In other words, by purchasing CIC with KES, recycling plants are able to acquire a higher volume of PET plastic for a lower KES equivalent compared

How can we use Blockchain CIC to create a PET circular economy?

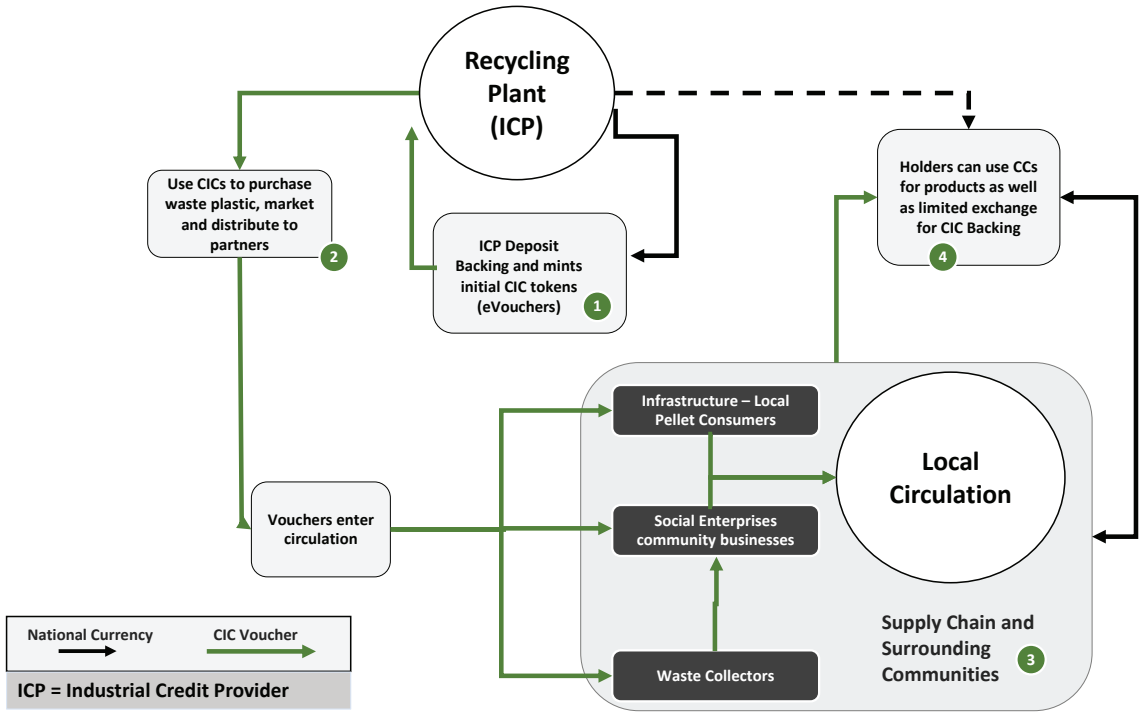


Diagram A

to purchasing the same plastic outside of the network. This is possible thanks to the strong CIC purchasing power inside the community which allows individuals to buy goods and services in CIC.

In Diagram A (Adapted from the Grassroots Economics Foundation). Recycling partners such as KAM and PETCO would be assisted by UNEP to create a reserve fund (1) and CIC's from the Sarafu Network would be created based on the size of that fund (Generally 4x leverage is possible). (2) CIC are offered as an extra incentive for PET waste collection and also seeded into local supply chains (3). CIC can be used to redeem pellets from recyclers and can also be used to cash-out the reserve fund over time (4).

Access to data is a key barrier to environmental management; with blockchain registered CICs UNEP is attempting to commodify PET trash and boost local economies.

The complexity of a system approach is to share and integrate various forms of public, private, platform-based user-generated and citizen science data that can speak to environmental change, socioeconomic patterns as well as human behaviors, networks, perceptions, and sentiments. This pilot project in Nairobi is just an example on how technology can disrupt the way cities incentivize and engage with inhabitants to achieve the Sustainable Development Goals. After the pilot, the PET CIC system will be able to scale up to other municipalities, counties and at large Kenya. Eventually not only this digital ecosystem can be replicated to other countries but could also become a baseline technological architecture to commodify and manage other type of waste in a more secure, transparent and immutable way. This co-creation of community-based initiatives will build a bottom-up methodology for societies to evaluate their own sustainability and plan for a more sustainable future.

Image 1 | Kenya: A social business in an informal settlement part of the Sarafu Network

Dynamic and interactive, the dashboard not only is the starting point for policy making but it is also a transparent and more accessible tool to inform citizens on important public issues.

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What is the driving engine of urban innovation?

The answers are various application scenarios that pervades cities. From the perspective of physical layer, the scenarios are the entrance to urban system for citizens; from the perspective of digital layer, the scenarios are the hubs for data generation and application.

Real and virtual, humanity, art and technology explore the fusion in the scenarios. The theory of scenarios originated from film and drama field and was extended to the field of urban development by Terry Nichols Clark of the Chicago School. Urban space is expanded from the natural and social level to the social attribute, and various public service facilities integrate with different social organization relations of different groups of people.[1,2]
It breaks through the perspective of traditional producers and suppliers. Experience, culture and value pursuit are chained with fundamental urban functions from the perspective of consumers or users.

The role of social ties also generates more scenarios. Another side of the scenario for future city comes with the list of opportunities for innovation. The scenarios will become a 24-hour roadshow and incubation base for landing, testing and iterating new technologies, as well as an energy field for the blending of culture, art and technology.

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SECTION 3

APPLICATION SCENARIO PROGRESSION

Who will enter the 'Hall of Fame' in the digital age?

Application Scenarios in the digital age: An integrated perspective of technology, business, and urban development

Mingxiao Zhao , Keli Zhu
Institution of New Economic Development
China Institute of New Economy of Development Research Center
of the State Council of China

For the past decades, scenario has been used by both private sector and public sector to propose a potential event or a series of events that could affect the direction things are headed to measure risks, develop products, design strategies and policies. At the forefront of the Fourth Industrial Revolution, application scenario is pervasively used by technicians, marketers, entrepreneurs and investors. The phrase deviates from the original meaning of scenario while the functions remain and extend. With the user base of this phrase expanding beyond business domains, what it represents is far more than commercialization of technologies.

Application scenario describes a real-life situation in which new technologies could be extensively applied to achieve a goal, whether it is to solve problems, provide experiences, complete tasks, or a mixture of above. Further illustration is worthwhile. First of all, new technologies refer to general purpose technologies (GPTs) represented by next-generation information technology (Next-generation IT), such as Internet of Things (IoT), artificial intelligence (AI), cloud computing and blockchain. GPTs possess four basic features: wide scope for improvement and elaboration, applicability across a broad range of uses, potential for use in a wide variety of products and processes, and strong complementarities with existing of potential new technologies.[1] Examples of GPTs are the steam engine, electricity, and information and communication technology (ICT), which are all primary driving forces behind the past three industrial revolutions. GPTs can be used in wide applications. Thus, they not only affect the entire economic system but also bring about changes in social norms.

The Fourth Industrial Revolution would have a much more profound and revolutionary effect on human society, since Next-generation IT could digitalize almost everything and penetrate into each real-life situation. With different combinations of technologies,

Application scenarios convey a hint of prototypes of future cities.

various new products, solutions, and models are created to meet the needs in a certain situation. The availability of new tools is tending to induce people to abandon their previous behaviors and employ new methods, which in turn change people's habits and behaviors. Thus, application scenarios in the digital age, like production plants in the industrial age, can be viewed as laboratories for the exploration of natural processes and as centers of research of new tools,[2] both of which are still of service to risk measurement, product development, and strategic planning. Application scenarios, whether it is an existing situation reshaped or a previously nonexistent situation made possible by new technologies, constitute a complex space, where the fusion of physical and digital world is the new habitat for humanity. Each person, whether they like it or not, is deeply involved in the process of this immense scenario experiment and paradigm shift.

An Expanding, Interactive, and Evolving form of Value Creation

From the point of economic development, new applications usually mean commercialization of technological breakthroughs,[3] such as locomotives and textile machine powered by steam engine, electronic devices made viable by Li-ion battery, etc. Since the Fourth Industrial Revolution involves a systemic change across almost every sector and aspect of our society, we need a basic perspective to have a better understanding of the transformation in order to prepare for the future. Application scenario comprises the dynamic process of how a certain goal is achieved via use of new applications, collaboration among players, response to environment, and movements in space. Each process is digitalized via installation of interrelated hardware, such as sensors and devices, as well as software to record operations, facilitate actuations and gather feedbacks. Thus, application scenario forms a closed-loop of value creation. Deconstruction of application scenario helps us get further insights about changing norms of our society.

The most prominent feature application scenario in the digital age is the emergence of the new factor of production: data. "Data is the new oil." The analogy fits in some ways. Like oil, data is an important strategic resource for nations nowadays. Data needs processing to unleash its enormous value just as oil needs refining. Whereas there are four significant differences between oil and data which challenges several basic assumptions which economic theories are built upon and key to the new structure of application scenario. Firstly, unlike the limited supply of oil, the volume of data is constantly increasing with expanding placement as well as improvement in precision and sensitivity of sensors.

Data takes various formats such as numbers, words, pictures, audios, videos, etc. An evaluation made by IBM indicates that 90 percent of world data has been created in the past two years.

Secondly, oil is corporeal and occupy physical spaces. Thus, oil and oil products are exclusive, which could not be processed or used by multiple sides simultaneously.

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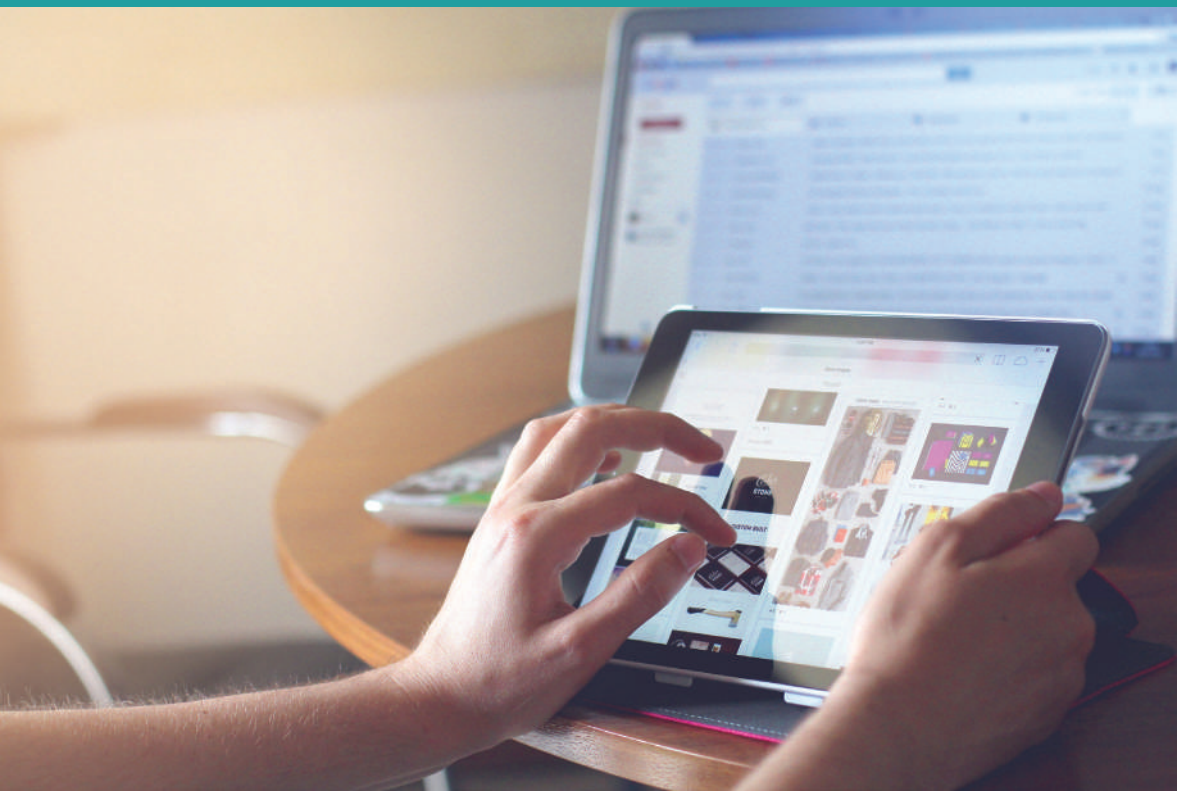


Data is intangible and not limited by physical spaces. Thus, data and data products could be processed and shared unlimitedly at the same time. In addition, the costs of making copies is almost zero.

Thirdly, transportation of oil requires huge amount of resources and takes time, which depend on the speed of vehicles. While data can travel at the speed of light, which enables instant delivery, interactions, and feedbacks. Thus, things are evolving with quick iteration and high velocity. Last but not least, discoveries of oil and usages of oil products are normally not at the same place. However, data is generated and new applications resulted from data analysis are adopted in the same application scenario, while the same data can still be repurposed for use in scenarios different from which it is originally collected.

Based on the above analysis, unlike the value chain of oil, value creation in application scenario follows a circular, evolving, and expansive form which can be decomposed into the following four layers.

Scaling Resources:
Oil is found in relatively few places, but data can be found everywhere. Like discoveries of oil fields, data is generated when each new sensor is installed in an application scenario. Despite the Internet of Things connecting billions of devices worldwide, technicians endeavor to create Internet of Bodies with applications such as Google Glass and digital implants in human bodies.[4] With advances in capacities and materials, the extreme phenomenon of usage of sensors is called "smart dust", where physical space is laced with ubiquitous nano-sensors so that they disappear into the environment. Sensors combined with software, which records whole processes of how things happen in an application scenario, accomplish the mapping of the physical world to the digital world. The significant difference between the mapping and ERP is that the former is recording how things naturally happening while the latter tries to implement standard process based on so-called best practices to achieve management efficiency.[5] Besides sensors and software, new generation of communication networks, such as 5G, quantum, and low-earth-orbit (LEO) satellites, with their low-latency, high-bandwidth and advanced stability, are expanding the kinds of data that can be frequently transported with improving quality. These digital infrastructures, like roads, bridges and railways in physical world, construct the framework of application scenario in the digital world.

Power Engine:
The internal combustion engine is one of the major power engines in machine age, which turns the chemical energy of oil products into heat, powering mechanical motion based on the known laws of physics and chemical reactions. Data also needs processing and transferring so that it can be turned into useful work. The power engine of unleashing the intelligence of data is the combination of computation and algorithms, while the former decides the processing volume and speed, the latter decides the quality and quantity of findings. Over the past decades, computation has depended on the performance of hardware, such as integrated circuit, clouds, data centers, and its costs, basically following Moore's Law. Algorithms, similar to laws

The last thing to mention is that change in the paradigm has profoundly reduced the need to "own" but increased the necessity to "link" . For example, Airbnb provides short-term house renting without holding any houses and used to suppose the market capitalization of the world's largest hotel chain Marriot.

of physics and chemical reactions, initially developed to make computers capable of thinking like humans and trained by human knowledge. However, compared with human's limited brain's ability to collect, store, and process information, algorithms are evolving to depend less on human knowledge and developing meta-methods that can find and capture the arbitrary complexity of the world.[6]

Joint Production and Actuation:

In the digital age, the volume of data is exponentially increasing and could be shared simultaneously at nearly zero marginal cost, which facilitates communication among different producers and inspires creativity. Network effect, which indicates the more participants the greater the value produced, is inducing changing logics of organization. Production paradigm shifts from competition of limited resources and vertical linear division of labor from the machine age to coordination, integration and cross boundary. Take the ride-hailing scenario for instance, the task of getting the passenger to their destination is joint completed by hardware (i.e., mobile phone and car), software (i.e., Didi/Uber and Baidu Maps/Google Map), and services (i.e., drivers and other customer services). Along the trip, the passenger could conduct a series of behaviors such as replying emails, watching a movie, or listening to music which provided by other producers via the mobile phone. Thus, an application scenario is like a mini ecosystem, where producers work together to meet concurrent needs. Furthermore, sharing data by producers is very likely to help them find more patterns and correlations among their businesses via the power engine computation and algorithms. The player who builds advanced digital infrastructure and uses data intelligence to reshape or create a scenario is usually the holder of the platform, which attracts multiple sides of players to the network and helps them by enriching the kinds of products they could provide.

The last thing to mention is that change in the paradigm has profoundly reduced the need to "own" but increased the necessity to "link." [7] For example, Airbnb provides short-term house renting without holding any houses and used to suppose the market capitalization of the world's largest hotel chain Marriot.

Enhancement and Reproduction:
A traditional value chain normally includes divided phases such as logistics, R&D, operations, distribution, marketing and sales, each carried out by relatively independent units in different locations. As digitalization is expanding along the value chain, time and distance are squeezed. Data flow enables distinct phases to inform one another and creates an instant feedback system in each scenario, which results in rapid iteration of products and services. Massive interactions enhance diversity, quality, and efficiency in an application scenario. Enhancement is just one side of the story. Data is usually being used for other scenarios different from ones where it's originally created. For example, data from digital bracelets can not only enable fitness apps to recommend customized training classes to users but also can help doctors diagnose and treat patients. Besides data, data products, such as Zhima Credit and FICO, also play the role of "common denominator", vastly used in an array of scenarios and building more connections. Data intelligence helps value creation replicate in similar kind of scenarios and extends to reproduce related scenarios. Hence, more and more connections are built among diverse scenarios, which stack together create an evolving multidimensional form of value creation.

Family Enterprise, Conglomerate, Platform, and What is Next?

When family enterprise is not compatible with steam and electric power as well as the large-scale plants needed to exploit them,[8] the strategy and structure of business evolved into industrial conglomerates, which normally started from controlling and integrating supply chain of related business divisions to achieve accumulation of wealth and then savagely expended to unrelated businesses via M&A activities. The "Hall of Fame" in the machine age lists corporate giants, such as General Electric (GE), General Motors (GM), United Technologies Corp (UTC), and Siemens. However, there was a wave of restructurings of the conglomerates in the 1960s and the 1970s, the overarching argument was that the break-up value of the conglomerates was higher than the sum of the value of the divisions.[9] And the wave is spreading out in the 1980s as "condemned to extinction" and reflected in the break-ups and spin-offs of these conglomerates nowadays, especially marked by the turmoil of GE.

While the industrial conglomerates are struggling, shrinking and falling, Bain noted that 2018 was the first time when global M&A activity was dominated by deals taking firms into new lines of business.[10] This phenomenon is led by technology companies, such as Amazon and Alibaba, which took 7 seats of the 10 largest companies by market value in 2019 and generally adopt platform strategy. Even though there are various factors behind the performance differences, management

Ranking	DEC-1999	DEC-2009	DEC-2019
1	Microsoft	PetroChina	Saudi Aramco
2	General Electric	Exxon Mobile	Apple Inc.
3	NTT DoCoMo	ICBC	Microsoft
4	Cisco	Microsoft	Alphabet Inc.
5	Walmart	HSBC	Amazon.com
6	Intel	Walmart	Facebook, Inc.
7	Exxon Mobile	China Construction Bank	Alibaba Group
8	NTT	Petrobras	Berkshire Hathaway
9	Lucent	BHP Billiton	Tencent
10	Royal Dutch	China Mobile	JPMorgan Chase

Top-10 Most Valuable Companies in the World by Market Cap.

capacity is a key, i.e. the capacity to collect and process mass information, make high-quality decisions, mobilize resources, and act agilely act. Unlike the industrial conglomerates' integrating of unrelated businesses in order to achieve diversification, most technology giants start from a single type of scenario, penetrate and create a wide array of connected scenarios via the "common denominator", and finally build a formidable ecosystem. Here we take Ant Financial for further illustration.

Ant Financial, officially established in 2014, is a member of the Alibaba digital economy and the highest valued FinTech company in the world. Its predecessor is Alipay, an online payment service launched in 2004. Though there is a wide collection of case studies about Ant Financial, we divide the evolution of Ant Financial into three phases of how four layers gradually forming the giant. Alipay is initiated for building integrity of e-commerce. In 2004, Alipay built a virtual account system to combine transactions to similar entities in order to ease pressure of the system, improve efficiency, and reduce costs. Each trader gets a unique ID is the innovation that records flow of money and logistics naturally. The phase from 2004 and 2010 is when Alipay built

the digital infrastructure of the e-commerce transaction scenario and accumulated a mass of transaction data.

The innovation that Alipay gapped away from competitors and reshaped the online transaction scenario is the quick payment service in 2010. Before this, Alipay only provided the access which redirected traders to e-bank services offered by partner banks with redundant steps to complete a transaction. User experience is poor with low rate of successful payments. With negotiating with a few partner banks, Alipay was authorized to complete a business transaction as an agent. Traders only need to attach bank accounts to their Alipay accounts and sign the quick payment service, for which Alipay unified and squeezed redundant steps of different banks into one. This process re-engineering turned Alipay from a follower who obeys the rules set by traditional banks to a disruptor who leads the trend. Within one year, more than 160 banks signed agreements with Alipay for the quick payment service. Alipay was rebranded as Ant Financial Services in October 2014.

The quick payment service lie the foundation of mobile payment, which is the common denominator now pervasively applied in daily life scenarios such as payment of utilities, public transportation, supermarkets, and entertainments. Another well-known common denominator bred from the online transaction scenario is Zhima Credit, which is the first personal credit score in China and swiftly applied to various scenarios. Along with the increasing application scenarios is exponentially rising data volume, which requires synchronous or advancing improvements in computation and algorithms. Throughout its history, Ant Financial continuously enhanced internal technical capacity to support data storage to reach the EB level and cooperate with world's top experts or institutions (establishment of Luohan Academy) to develop cutting-edge algorithms. The four layers are ceaselessly reinforcing one another.

Most of the seven largest technology companies start from reshaping a single scenario and extend to a wide array of scenarios via forming the four layers. The digital infrastructures evolve to multisided platforms, which facilitate interactions or transactions among multiple participants and are the mainstream of business strategy in the past 30 years. A new trend is emerging now. Google's sibling company Sidewalk Labs won the bid of Sidewalk Toronto in 2017 and created the Master Innovation Development Plan (MIDP) in 2019, which aims to utilize technology to create a smart urban area that improves the quality of life of its residents.[11] Alibaba Group and other technology companies coordinate with Hangzhou Municipal Government to develop Hangzhou City Brain, which is a public AI system assisting the government to solve problems of transportation, security, municipal construction, urban planning, etc.[12] Starting from building digital infrastructure to reshape or create a scenario is increasingly obvious.

More recently, on January 7, 2020, the first made-in-China Tesla Model 3 vehicles were delivered to consumers and priced between $50,000 and $60,000. The market cap of Tesla Company is larger than the sum market cap of GM and Ford Motor Company. One of Tesla's core competence is digital intelligence and

Autopilot driving system via self-developing operating system, OTA, and chips. With largest scale of Autopilot electronic vehicles, traffic environments are digitalized, and data of real road conditions are continuously collected for deep learning to strengthen the Tesla intelligence further. Tesla is building digital infrastructure for future mobility. But how will it evolve? A platform or an operator who would be deeply involved in urban planning? What is the relationship between these technology giants and governments?

Tokyo is the most populated city in the world with around 38 million residents, while Facebook has more than 2 billion users actively interacting online.

The unlimited digital world has already surpassed physical boundaries.

Prototypes of Future Cities and New Economy

Modern cities are profoundly shaped by two innovations from the First and Second Industrial Revolutions. Cars drive cities outward and lifts push cities upward. The applications in transportation and residentials scenarios induced people to abandon previous tools, such as carriages, tramways, and stairs, and form new habits. Changing norms in turn drive more demand and further develop new industries, whereas industrial giants, such as GM and Ford for cars, Kone and Otis for lifts, dominate the markets. In his book Inventing Future Cities, M. Batty says cities lie at the root of how new technologies are popularized and disseminated – not invented necessarily but developed and spread.[13] Cities act like test ground. New technologies, in return, are used in all sorts of applications which reshape existing scenarios or create new scenarios. Numerous scenarios with relatively independent functions are like prototypes of cities' different facets, which convey a hint of what future cities look like and where new driven forces of economic growth are.

Up to now, the Forth Industrial Revolution has triggered major changes of urban form, functions, and economy. Despite continuous urban sprawl symbolized by city clusters and megacities,[14] cities are gradually digitalized from a bottom-up approach via connecting various application scenarios to form a digital world, where interactions are intensively taking place with high frequency whereas distance is becoming irrelevant. Though "digital twin" is commonly used to describe the new form of cities, the structure is much

more complex than one to one mapping. For instance, Tokyo is the most populated city in the world with around 38 million residents, while Facebook has more than 2 billion users actively interacting online. The unlimited digital world has already surpassed physical boundaries.

The function of cities evolved with productivity level. It undergoes two major transformations: as a container to collect and preserve enough goods to sustain basic needs for human survival in the agricultural age and then as a hub to facilitate allocation of resources and creation of goods in the industrial age. Current cities, in which application scenarios act like reflex with ubiquitous sensors, digital intelligence and actuations, are continuously scaling, learning, enhancing, and reproducing. Cities are becoming more like an organism or extension of the brain, which would actively interact with people or response to environments automatically. Humans are very likely to shift form living in cities to live with and co-evolve with cities.

The application scenarios embedded in the Urban Eco-park System include entertainment, recycled waste, and environment protection.

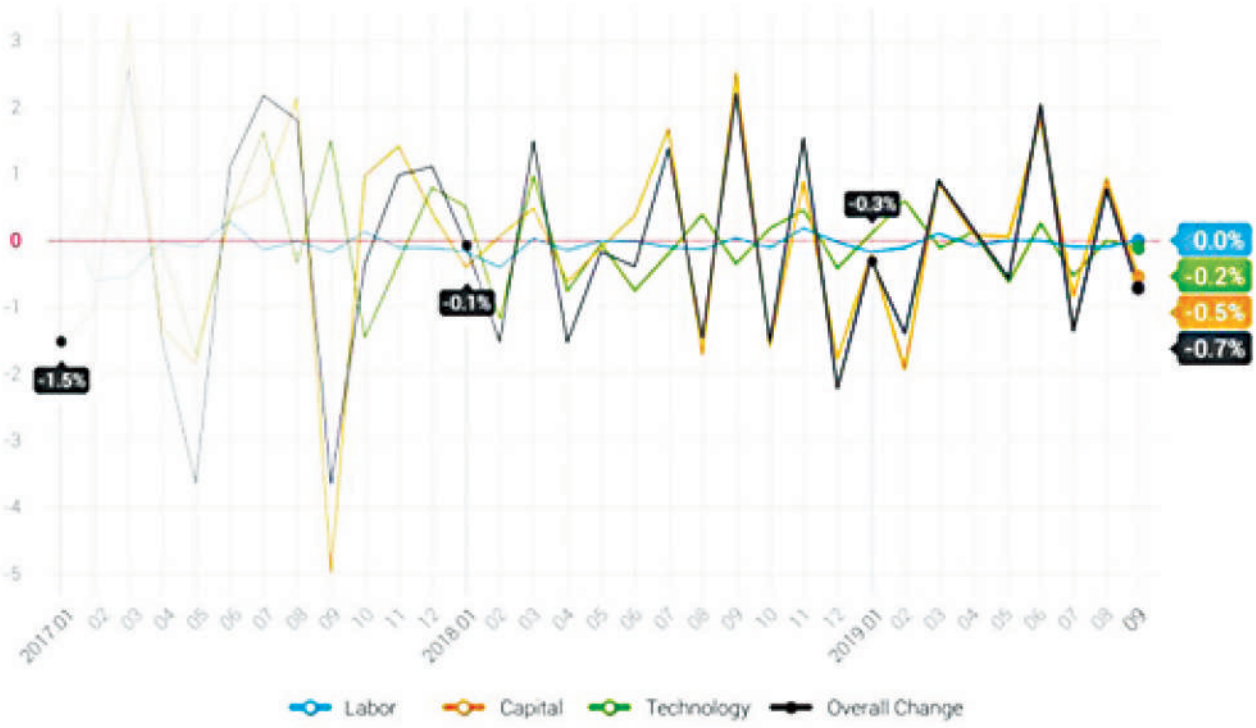
Even though measuring economic output in the digital age is difficult, the growth driven by these technology companies is scaling up. For example, Amazon announced plans for a second headquarter (HQ2) in September 2017 and attracted more than 200 cities worldwide to apply. In the Request for Proposal of HQ2, Amazon released the contribution of its headquarters to Seattle from 2010 to June 2017, reaching an amount over $80 billion including capital investments, compensation to employees, indirect gains from its investments, etc. Despite the direct economic output, Amazon acts like a magnet which attracts the best talent in the industry to work in Seattle. The knowledge exchange through Amazon's cooperation with the city and those who left the company to start their own business in the city create spillover of Amazon's digital intelligence, i.e. computation and algorithms as well as network effects, which empower the city to expand in digital world beyond its administrative division. The economic output of the city is the sum of value created in physical and digital worlds.

The Concept Design of Chengdu's Urban Eco-park System

A Systematic Innovation for Inclusive and Sustainable Urban Future

Realizing the Forth Industrial Revolution is generating profound reforms. Chengdu, the megacity centered in western China, is pioneering in systematic changes for a new urban future with inclusive growth and sustainable development, where citizens, nature, and economy share prosperity. In the digital age, the city is becoming more like an organism, which is growing with more complexity and continuously expanding outward and upward to inhabit increasing number of citizens.

The doctrine that promotes divided functional order (i.e. division of land according to residence, production, commercial, etc.) and lays the foundation of modern urban planning, the Athens Charter proposed by Le Corbusier, and the urban fabric of concentric zones and radial networks are collapsing. In addition, with widespread network effects and agile production, each person and each community could be a production unit. As knowledge-intensive industry takes more proportion of



Primary Input Contribution to NEI

GDPs, the geographic location of future works is more flexible. Observing these trends, Chengdu is reorganizing urban economic production through 66 self-sustained communities according to industrial basis, such as new materials, biotech, trade, culture, and creativity. Via reallocation of resources, each community consists of relatively full functions like working, living, schooling, and entertainment to relief dense population while ensuring economic opportunities. Moreover, to prevent ecological damage caused by urban sprawl and ensure the harmony between people and nature, Chengdu adopts the idea of a "Park City" aiming to reserve natural area as much as possible and now is building the world's largest urban eco-park system covering an area of 1,275 square kilometers.

Sustainable growth is driven by applications of new technologies, which demands institutional and ideological adjustments.[15] To achieve diversified technological exploration and develop new economy, several challenges remain, such as the lagging segregation of duties lagged behind technology and business advancements, information asymmetry in the market, and the difficulty in measuring digital economy. Besides market mechanism, governments play an active role in resolving the obstacles.[16] Chengdu conduct an innovative approach by setting a special government department-Chengdu New Economic Development Commission ("NEDC"), which aims to facilitate coordination among other departments within the government to dissolve institutional barriers hindering the incubation of innovation and work closely with private sector, universities and research institutions as well as NGOs to anticipate major challenges from the shifting paradigm and respond to needs.

NEDC deploys several policy innovations. The one of extensive influence is the "List of City Opportunities", which the government starts from its own potential application scenarios, such as digital governance, public services,

and public placemaking, to collect information of needs and regularly released to the public, which improves the transparency of public procurement and encourages positive competition. Chengdu has launched around 1,400 items and matched 62 cooperation. The list creates incentives to technology companies and facilitates them to find where markets are, especially MSMEs, to create new methods to address social issues via new technologies, products, services, or business models. For example, the application scenarios embedded in the Urban Eco-park System include entertainment, recycled waste, and environment protection. A start-up called Aobag got an opportunity from the city's environmental protection bureau, encourages individuals and organizations to use social media to sign up and collect their recyclable wastes in recycled bags. So far, they have 214 organization users and 32,767 individual users and recycled 442,248 kg waste and got fund from Expo Live.

Another case is coordination between the city' Smart Governance Center and technology company SZL, which deploys satellite remote sensing data to improve the quality of water in rivers and lakes. Last but not least, NEDC deploys a new measurement New Economy Index (NEI),[17] which includes labor, capital and technology inputs that account for 40%, 35% and 25% of the total weights of the index, to trace the growth pattern of the new economy sectors and focusing more on the quality of the economy instead of quantity.

During the writing of this article, our home country China and the people are combating with coronavirus 2019-nCov. We are in deep grief about the tragedies caused by the epidemic. However, we still see the extraordinary measures that Chinese authorities, companies, and people have taken to tackle the coronavirus outbreak. Digital tools are intensively deployed to research and monitor the outbreak, dispatch tons and thousands of goods, broadcast latest news, and stabilize society when hundreds of millions of people choose to stay indoors to prevent the spread of the virus. For instance, the AI satellite network company ADAspace co-works with mass media to instantly release national epidemic prevention and control policies to the public through the "Earth Live" App and shares satellite remote sensing images and geographic information to help government to monitor epidemic areas.

So, what do future cities look like? They might form the shield for people in need, provide opportunities for diversified thought experiments, and satisfy people's fervent wish for a better life. Ultimately, cities are very likely to evolve as best friends of mankind. Only when we share prosperity with cities, we might reach, what Ed Glaeser celebrates, the Triumph of the City.

442,248 kilograms

of waste recycled by Aobag

Comparison images of Hankou Railway Station before and after the 2019-nCoV outbreak [18]

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Lean government for lean tech

The role of local government in mobility innovation

George Economides
Oxfordshire County Council

The acceleration of global urbanisation is taking place at the same time as rapid advancements in mobility technology. By 2050, around 70 percent[1] of the global population will live in cities. As our cities grow, the way we move around them is changing; much of the technology at the heart of that change is driven by connectivity and increasing automation.

Implementation of new mobility technology offers opportunities to make progress towards UN Sustainable Development Goals of fostering innovation (SDG 9) and promoting economic growth (SDG 8). Local and regional governments have a key role to play in making sure societal benefit is balanced with economic opportunities as we build the transport infrastructure of the future.

With local governments geared towards long-term economic stability, there is a tension between the need for fast-paced, competitive technological innovation and the tendency for local authorities to be risk-averse. Dedicated innovation teams within local government structures are needed to explore ways that publicly funded bodies can maximise societal benefits and facilitate sustainable business models in a time of rapid innovation in mobility technology. Oxfordshire County Council has created an innovation and research team known as iHUB to address such challenges and actively engage in the innovation process collaboratively. While remaining part of the county council, the iHUB team is mostly externally funded and focuses on innovation projects with industry and academia to deliver step changes in areas of rapid development. Within iHUB, I lead the connected and autonomous vehicle (CAV) team, the first of its kind within a UK local authority.

Oxfordshire County Council's iHUB has been instrumental in developing links to business and academia as well as securing external funding for mobility projects. These range from on-road trials of CAVs, cybersecurity, and communications-focused projects to strategic modelling and asset management. In just two and a half years, the CAV team has organically grown from two to nine externally-funded staff members and is now breaking new ground: engaging with unmanned aerial vehicle (UAV) and quantum technologies. The team has acted as a catalyst for innovation within the council, and its success demonstrates the important role that local government can play in meeting UN Sustainable Development Goals.

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Technological drivers

Rapid technological innovation and shifting demographics have created a time-critical pressure that has enabled the emergence of CAVs and other new mobility innovations worldwide. Artificial intelligence (AI), faster computing, new sensors, and improved connectivity have enabled CAVs to begin operating in complex environments. In Oxfordshire, we have been trialling CAVs for three years in both urban highways and rural environments[2] through the DRIVEN project. This was 30-month innovation project (2017-2019), carried out by a consortium of ten world-leading organisations. The project covered all technical aspects to deploy fleets of autonomous vehicles in mixed traffic. It included CAV trials, risk assessment, communications, cybersecurity, insurance, smart infrastructure, fleet management systems, etc.

Meanwhile, advances in battery technology are not only enabling faster adoption of electric vehicles, but are also giving rise to a new micro-mobility industry projected to be worth up to £380 billion worldwide by 2030.[3] Smartphone ownership is growing rapidly, with 70 percent of the global population projected to own a mobile phone by 2025 with much of the growth being driven by emerging economies.[4] Mobile connectivity has enabled new data-driven digital services and business models that are disrupting and transforming the mobility industry. On-demand and demand-responsive ride-hailing and ride-sharing services are competing with traditional taxi businesses.

Dedicated innovation teams within local government structures are needed to explore ways that publicly funded bodies can maximise societal benefits and facilitate sustainable business models in a time of rapid innovation in mobility technology

These services are changing our understanding of public transport, and their long-term social implications will change how we plan for transport provision in the future.

Local governments have to prepare for a future where urban, peri-urban, and rural mobility is transformed. CAVs, electric scooters and on-demand services linked by aggregators like Moovit are all part of the smart city ecosystem that is beginning to emerge. The role of local government is to enable sustainable growth by engaging with the market, building the minimum viable necessary infrastructure, and sharing best practice with other regions to facilitate adoption while ensuring lasting societal benefit.

The fourth industrial revolution

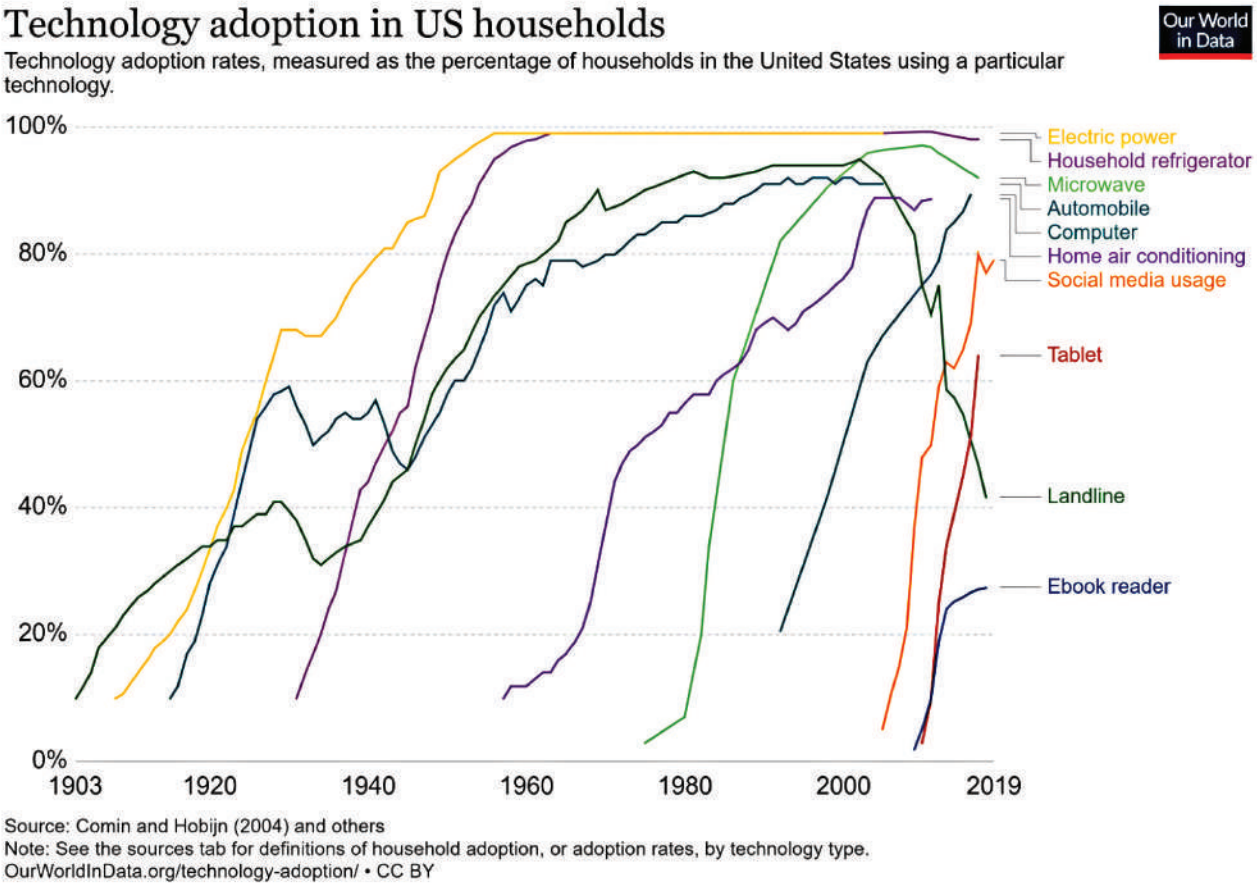
Mobility innovation is taking place in the broader context of what some are calling the fourth industrial revolution. Brought about by connectivity, digitisation, and automation, the fourth industrial revolution is set to transform our cities at unprecedented speed.[5] Once a scalable dominant design for CAVs is established, their widespread adoption in cities could be rapid. While the exact timeframe for mass adoption is difficult to predict, there are historical examples of radical changes in mobility that we can draw upon to inform our estimates. The transition from horse-and-buggy to automobiles at the beginning of the 20th century is one such example. A photo comparison[6] of traffic on New York's 5th Avenue is sometimes used to illustrate this. Horse-and-buggy transport accounted for almost all traffic on the street in 1900. Just 13 years later, traffic on the same street consists almost exclusively of automobiles.

While CAV technology is yet to find a dominant design and scalable business model, it is worth noting that technology uptake is much faster than it was in the early 20th century [figure 1].[7] According to the most ambitious predictions, our cities are poised on the brink of mass adoption of CAVs [8] with an estimated global market capitalisation of up to £100 billion by 2035.[9] Regardless of the precise timeline of mass adoption of CAVs,local governments around the world need to prepare for it as the testing phase of CAVs gathers pace. Oxfordshire is already home to the Zenzic CAV testbed ecosystem and is hosting an array of CAV projects including: Oxbotica, FiveAi, Dynium, Arrival, StreetDrone, and Roborace. Waymo, Google's autonomous vehicle division, has chosen to base its first European engineering hub in Oxford after acquiring a simulation technology company founded by Oxford academics called Latent Logic. The council is working closely with these companies to understand the technology as it develops.

Preparing for mass adoption of CAVs is especially important for urban local authorities in emerging economies, which in some cases can see adoption of new technology even more rapidly than elsewhere due to a process known as leapfrogging.[10] By adopting new technology once it has reached maturity, emerging economies can skip the iterative phases that preceded it. The early adoption of mobile payments in Africa is the most notable

example of this phenomenon – Kenya's SMS-enabled mobile payment system, M-Pesa, has been in use since 2007.[11] In these domains, the choices in infrastructure investment can be the make-or-break decision for a viable transition to connected and automated mobility.

Figure 1



Smart cities

Most of the progress to date in the development of CAVs has focused on the technology in the vehicles themselves. For private-sector innovators, this bottom-up approach makes sense – they are trying to build commercially viable vehicles that must operate using minimal or existing infrastructure. Local government and public bodies can take a more holistic, top-down approach by creating the digital infrastructure within which CAVs will operate. By helping to build secure data exchange platforms, local authorities can help to optimise urban mobility through traffic management while ensuring the provision of public transport and healthy modes of transport alongside private vehicles.

To enable this, there is a need for connectivity that spans urban, peri-urban, highways, and rural areas. While 5G's low latency and high bandwidth offers great benefit in dense urban areas, as well as potential returns to the infrastructure owners, a holistic approach bridging different protocols is needed. To enable CAV connectivity in and between cities, the vehicles and the data exchange platforms must be able to seamlessly switch between protocols like satellite, 4G, LoRAWAN and Sigfox. To bridge latency issues of lower bandwidth connectivity, infrastructure will need to combine edge computing and cloud services.

The other key consideration is the provision of high definition digital maps of the road and underground environments. As we move towards more automated and systematic communication between vehicles and traffic management, assets (e.g. traffic lights or water pipes) and demarcations (e.g. lane markings) need to be mapped in high precision. These "digital twins" will allow better modelling of potential solutions as well as live monitoring of urban environments. Moreover, high definition real-time digital mapping will allow for the digitisation of traditional physical infrastructure, such as parking meters, and more dynamic management.

While the connected environment itself may require new hardware – traffic lights that communicate directly with vehicles, for example – local governments should prioritise establishing their critical digital infrastructure and declutter the physical space. By actively engaging with new CAV suppliers, local authorities can communicate what are reasonable expectations for the public realm, including priorities like accessibility and walkability.

Local governments can also help to establish a cloud-based data infrastructure to deliver location data effectively to connected vehicles. If the process of CAV development is left to the market, we run the risk of a highly fragmented industry emerging in which different manufacturers' vehicles would run on different operating systems and, therefore, be unable to communicate effectively. If data is shared using common standards on a shared system, local government can play an important role in optimising traffic management and route planning systems.

At Oxfordshire County Council, our objective is to move from a system where traffic management is directed towards providing human drivers with information to a system

where autonomous vehicles, route planning apps, and roadside infrastructure like traffic lights are all sharing location data using a common system. This would represent a real step-change in the management of smart cities and would enable accurate predictive modelling, which is the desired future trajectory of current city management systems.

Funding models

Because of the traditional funding mechanisms available to government organisations, it is not always easy for local government to take the kinds of risks with public money that are normally associated with innovation.

Private Finance Initiatives (PFIs) – one of the traditional ways that local authorities have engaged with the private sector – offer a mechanism for public projects to be administered by private businesses. These contracts have the potential to become problematic for local authorities. They run the risk of becoming locked-in to long-term contracts that may become outdated and fail to take advantage of technological developments. Subcontracting thorough PFIs runs the risk of becoming an inefficient use of public money on balance.

New technologies offered by global businesses like Uber also present challenges for local government. Uber's technology provides a ready-made business model that requires almost no local development and offers rapid public adoption. Local authorities can find themselves in competition with each other to attract big businesses like this, but in doing so they can end up opening the doors to businesses that may not provide long-term public benefit. International businesses may not contribute tax in the jurisdiction and can easily leave the area if regulatory conditions become unfavourable.

New models are being explored by Oxfordshire County Council's iHUB team. One avenue we are pursuing is the Innovation Procurement Partnership (IPP) model. We hope it will allow us to modernise mobility while stimulating the local economy.

New approaches to modelling and procurement

At Oxfordshire County Council we want to introduce modelling that takes into account journeys that comprise multiple different modes of transportation or multimodal mobility. So, for example, an individual might cycle to the train station on a dock-less bike, take a train for a few stops, then catch a bus to their final destination. So predictive modelling systems and simulation technology needed for the management of smart cities need to take individual people into account and not just the vehicles they are travelling in. We also see the value of linking this to real-world demographics and validation methods from our sensors. This will eventually lead to a system that spans scales and timelines that will be able to inform planning more generally, from housing provision to traffic management.

Such a system would give us better data to plan future developments. It would allow

1.4 million pounds

invested by local authority into IPP

us to make the best use of public funds to invest in building new roads or cycle paths based on need and evidenced by data. Moreover, it would allow us to create a variety of hypothetical scenarios and provide a mechanism to evaluate solutions to these scenarios.

However, such a model is not currently available on the market. For this reason, Oxfordshire County Council initiated the UK's first Innovation Procurement Partnership (IPP), where the local authority is investing £1.4 million into a consortium to create a new product. Critically, the council will own part of the intellectual property (IP) generated by that investment and a profit-split arrangement has been made. Therefore, this approach creates a better product for the council's use, stimulates innovation in the market, and will create return-on-investment for the public bodies involved.

Iterative innovation

One common criticism of local authorities is that they're too slow to react to new challenges and opportunities as they arise. This is partly due to the timescales that local government operates which include long-term planning over several decades. It is also due to a tendency to be risk-averse which stems for the need to maintain financial stability and responsible use of public funds

However, at a time of unprecedented change in mobility technology,[12] prioritising stability might lead to missed opportunities that arise in a rapidly shifting landscape.

Glenn Lyons, Professor of Future Mobility at the University of the West of England (UWE), has argued that the "predict and provide" model for local government transport planning is outdated and suggests a "decide and provide" approach where the decision for which future should be enabled comes first and is guided by the values of the local authority.[13]

At Oxfordshire County Council, we are making the case for a more dynamic approach to transport planning to ensure that provision is constantly adapted to align with the values and priorities of the council[14] as the rate of technology adoption is too fast even for a decide-and-provide approach: the options between which decisions are to be made are still being developed in an agile and lean way while being rolled out.

Thus, as innovation is iterative, we are making the case for an "iterate and adapt" approach to mobility planning in local government.

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At the iHUB team at Oxfordshire County Council, we apply this methodology as a potential model to provide a mechanism within local government to become more agile and responsive in an era of rapid technological change.

In this context, the policy framework to describe the long-term vision of the council remains in place while the dedicated innovation teams are afforded the flexibility to iterate and adapt dynamically to market and technology changes. The innovation teams are still critically linked to the corporate principles, but the way that innovation is engaged with and evaluated needs to be more flexible given its highly-uncertain nature. For local government, investing in innovation in the ways described above can be thought of as comparable to buying insurance. When you buy insurance, you don't hope for a direct return on your investment. The money you pay up-front represents an investment in long-term de-risking by ensuring your systems are fit for purpose.

Building the future

Oxfordshire County Council has shown that local government can be a key player in driving urban mobility innovation locally and on the world stage. We are fortunate to be home to the world's most prestigious university and a number of world-leading institutions. By working closely with academia and helping to cultivate local businesses from the start-up stage to maturity, we have shown that it is possible to work with home-grown and

international stakeholders, researchers, and businesses in a way that ensures long-term societal benefit for the region. The council has also demonstrated that innovation in local government can drive economic growth and provide a model for councils to meet UN Sustainable Development Goals by becoming net contributors to the economy. Notably, we have been able to grow the iHUB team from 2 to 24 full time members of staff and attract more than £100 million in investment to the region. The CAV team in particular has been a partner to 15 innovation projects (funded by both the UK government and the EU) and contributed more than £4 million to the council's budget.

By introducing dedicated innovation teams within local government, it is possible to respond rapidly to technological advances in urban mobility even within risk-averse publicly funded bodies that operate over timeframes that span decades. The iHUB team at Oxfordshire County Council has helped to grow local mobility companies including Oxbotica, Latent Logic (recently acquired by Google's autonomous vehicle division, Waymo, to establish their first European engineering hub in Oxford), Zipabout, and Arrival/Roborace. The multi award-winning team, which has been running for less than five years, has shown that local governments can not only help to drive mobility innovation, but can also become world-leading experts in emerging technology and contribute to mobility policy development at both a national level and on the world stage.

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Live like you are in a laboratory

Co-creating the human city through design-driven innovation

Zhiyong Fu
Tsinghua University

Abstract

Replying to the uncertainty of urban development caused by the rise of science and technology, how can we apply the people-oriented concept and integrate the concerns of science and technology development with those of society and humanity to come up with innovative solutions? Facing the complexity of urban community problems, how can we use open-innovative methods and tools to promote public participation in creating harmonious communities? Achieving the goal of sustainable future development of cities, what kind of co-creation mode should we adopt to cooperate with international resources and contribute Chinese wisdom? Combining the exploration of human city in Tsinghua university, the research and analysis from the perspective of design-driven innovation, humanistic city, open innovation, and co-creation mode will be carried out to provide support and reference for social innovation practice.

Key words: Tech for good, human city, Living Lab, social innovation

Community design from the perspective of the Tech for good

Nowadays, artificial intelligence, big data, Internet of things, cloud platform, personalized manufacturing, intelligent production, and other new technologies and methods are constantly reshaping cities. And the physical space and digital network of cities are also integrated to form a complex ecosystem. The traditional top-down model of urban governance is insufficient to cope with the complex social and economic situation at the beginning. And the personalized requirements of citizens are increasingly prominent. Therefore, it is essential to adopt the bottom-up strategy and to use science and technology to creatively carry out the urban public service design and community reconstruction.

Tsinghua university has integrated design innovation into the transformation of society by technology and exploited a new mode of social innovation design. Different from the smart city infrastructure construction carried out by technology companies. Design innovation emphasizes the practical requirements of community and public services, improves the life of community

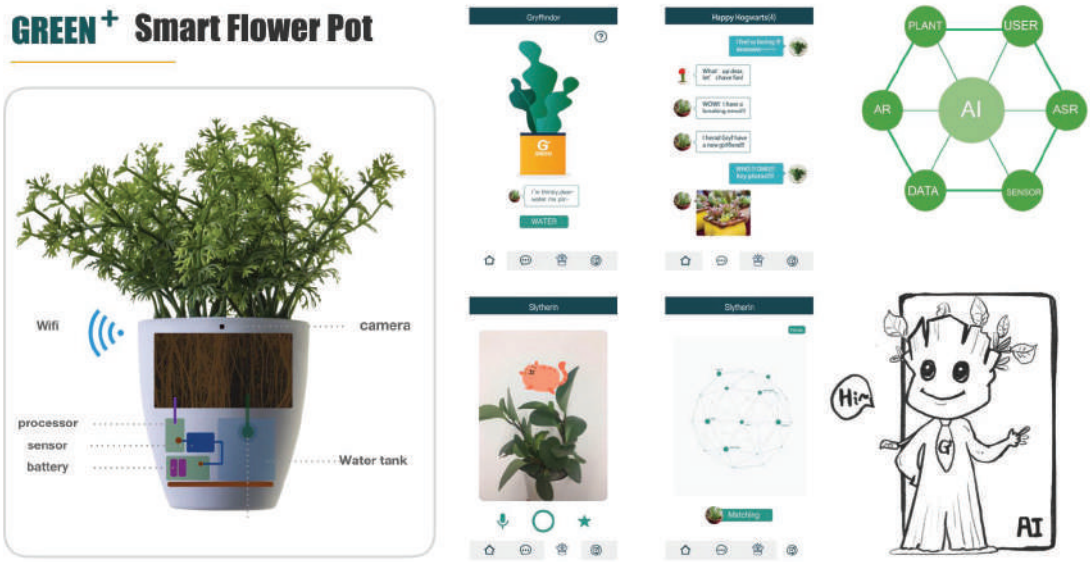

Fig.1 Green plus

Fig.2 Buildable

residents through the integration of design, technology, and business. Facing the requirements of community design, a series of design studies and project practices have been carried out to aim at different levels of needs such as management of community and residents, information exchange of residents, and emotional interaction between partners. Here are two examples from Tsinghua university's Santander 21st century challenge.

"Green plus" is a smart flowerpot that allows plants to communicate with people in the city. The user can water the plants with a button and talk to the plants via AI technology (Fig.1). "Green plus" uses flowerpots and apps to link users together and build an easy social network. Users can get together to discuss planting and share their work. In this way, "Green plus" brings a companion to young people living alone in the city. With the water storage, fertilizer storage, and soil monitoring system, users can remotely control and manage their plants through a button on the phone. When users use the AR to observe plants on their mobile phones, they can see vivid plants on the screen and even talk to the plants. The plants can tell the owners in human language when the plant needs help.

The Buildable project (fig.2) aims at the residents' requirements and improves their living space in Dashila. The mobile App is used to scan the layout and furniture of the interior space. After the spatial modeling is completed through image recognition technology, the furniture model of the database is used to build a new interior layout suitable for residents' life. Completion of design, the corresponding production requirements can be through the Internet platform to connect to the subsequent furniture production supply chain. There are a lot of "Taobao" villages in China, with their production capacity and efficiency advantages, can produce good quality and affordable furniture. People can properly improve life at the same time and, with the Chinese society, has established a new service pattern of community regeneration.[1]

In the above cases, the boost of science and technology makes everything possible. But from the specific cases to the implementation and promotion, the support of Open innovation laboratory mode is needed, which Open community Living lab is just attempting to.

Social innovation practice based on Living Lab

Increasingly, social problems are regarded as wicked problems, which need to be solved in an open and innovative mode. We proposed an innovative practice model based on the open community Living lab. Which carried out urban experience research for urban space and citizens' requirements, produced output for social influence and social change in the form of developmental workshops, community activities, and cooperative pilot projects, so as to achieve the goal of building a human-oriented city. "Living lab" is a research method with the diversity and evolution of the actual living environment: perception, prototype, verification and improvement of all kinds of complex solution." Stakeholders include residents, research institutions, NGOs, community and street managers, design firms, and others.

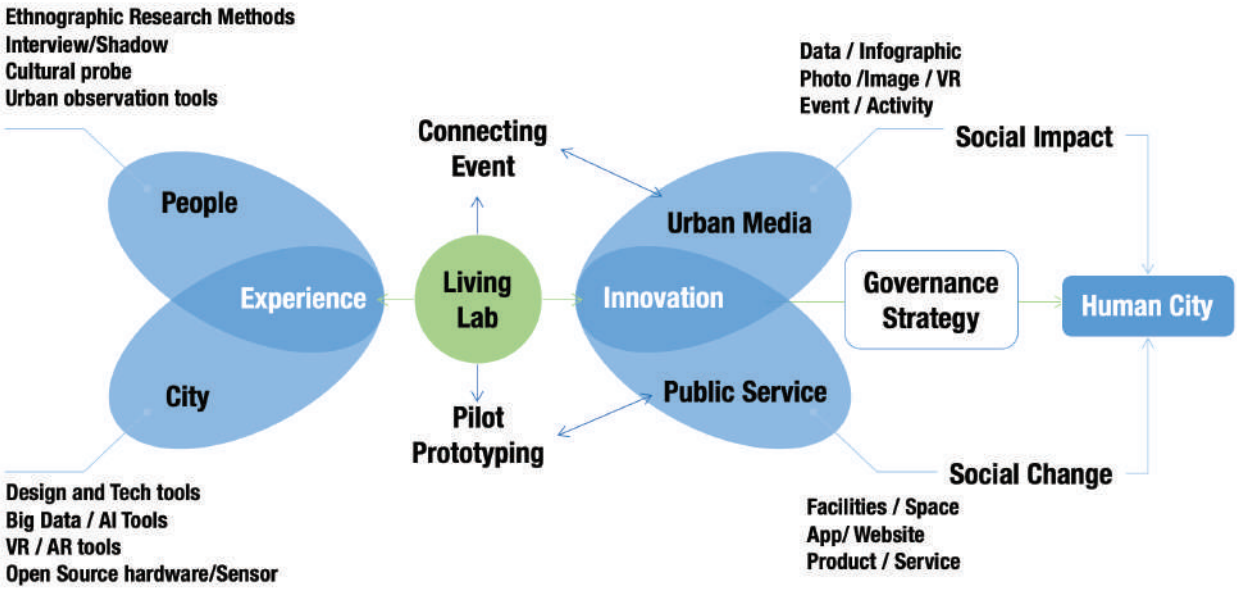

Fig.3 Humanistic Community Living Lab Model

We also take the process and tools of design thinking as the lead to develop tools suitable for open laboratory. The output of the results emphasizes the power of science and technology for good. The more participatory open source technology, low tech, social media, and other services applied to the community support the success of our model.

Living lab is a kind of innovative research tool used to improve the program and to develop the innovative products and services through the actual application of the test to enhance the applicability of products in the future market. Employment of user-driven, open innovation pattern enables users to also become innovators. Living lab researchers advocate methods that facilitate co-operation in teams with mixed expertise. These participatory methods provide a "third space"[2] for designers and users to meet. Artifacts or representations[3] that make sense to everybody facilitate cooperative work; they further promote mutual understanding and help make implicit knowledge explicit in the process.[4]

Humanistic Community Living lab model (Fig. 3) of Tsinghua university academy of fine arts. With the aid of courses, workshops, and summer program begin to add the thinking and resources to urban regeneration and Community experiment as the breakthrough point. In-depth, real social scene understands the concerns of Community residents and combines the power of information and technology to carry out public service design practice. In the areas such as Dashila, Fatou

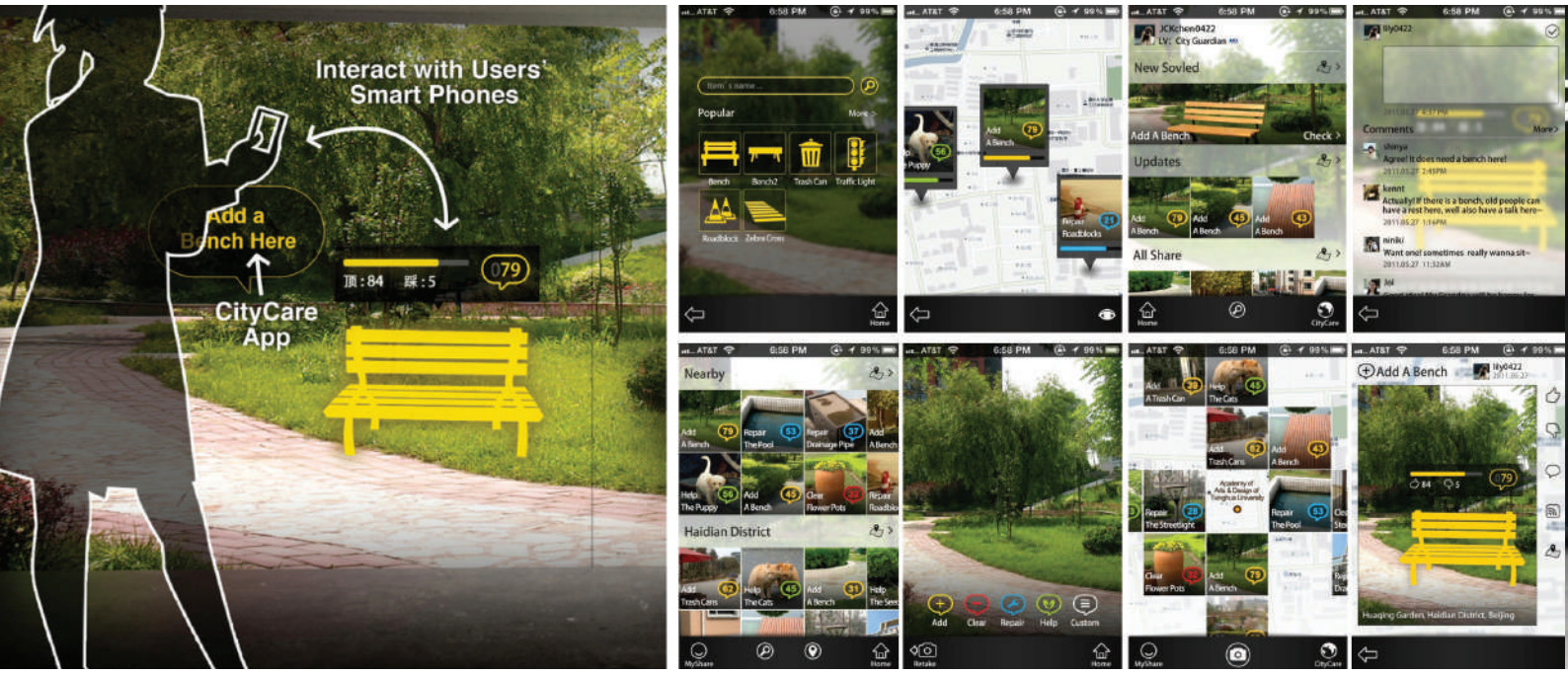

Fig.4 “CityCare” - a public participation information sharing platform for urban public services

regional cultural center, Yanjingli, and Fayuan temple, the application of opening laboratory mode has carried out a series of social innovation design activities. The Yanjingli project is a youth community, including co-living and co-working Spaces. We use it as a Hub to connect young people in the community with the residents of the surrounding community through art installations, community planting, community maps, and other projects during the Beijing international design week. Fayuan temple is a traditional community, and, in front of the temple, there is an open space. There is also a community activity space as crowds gathered place, we are geared to the needs of children and parents, set up community treasure hunt game, based on open source hardware interactive devices. It lets the participants gather information at the same time, a better understanding of community culture, and integrated into the community life.

“CityCare” (fig.4) is a mass participation, information sharing platform for urban public services. It encourages people to express their concern for the city by discovering and sharing various problems in the city, and thus promotes the construction of urban public services. Users post questions, rate questions, communicate on issues of common concern, and view city-wide problem distribution and trends on the web. “CityCare” evaluates and filters published questions through crowdsourcing. For problems with high attention and scores, “CityCare” will send

Fig.5 “Listen to our story”

them to the relevant departments according to the key words and classification of the problem. In “CityCare”, there is effective cooperation between problem publishers (users), problem owners (government and related departments), and problem solvers (related departments, enterprises and social groups) through information sharing on the platform to better improve the quality of urban public services.

“Listen to our story” (Fig.5) is a project initiated by information design student team from Tsinghua University. The project was held in 2017 in Yanjing Lane, a stylish new living space in Beijing. It is believed that people’s stories are the most valuable assets in communities. Stories connect not only people but also the group with the local space.

Project members believe that the core of the design of the community is the reconstruction of the interpersonal relationship and the relationship between people and space.[5]

Different from the traditional research, Living Lab method in the real world is studied: It involves multiple stakeholders and various interactive mode, allowes the user to play an active role as general innovators, and promotes the power of collective action. The explorations and practices make the urban and community development managers, designers, builders and investors, the perpetrators and user/citizens together create the laboratory. Actively participate in multidisciplinary research teams in a research environment. And taking joint collaboration to create a desired outcome [6] the more intelligent

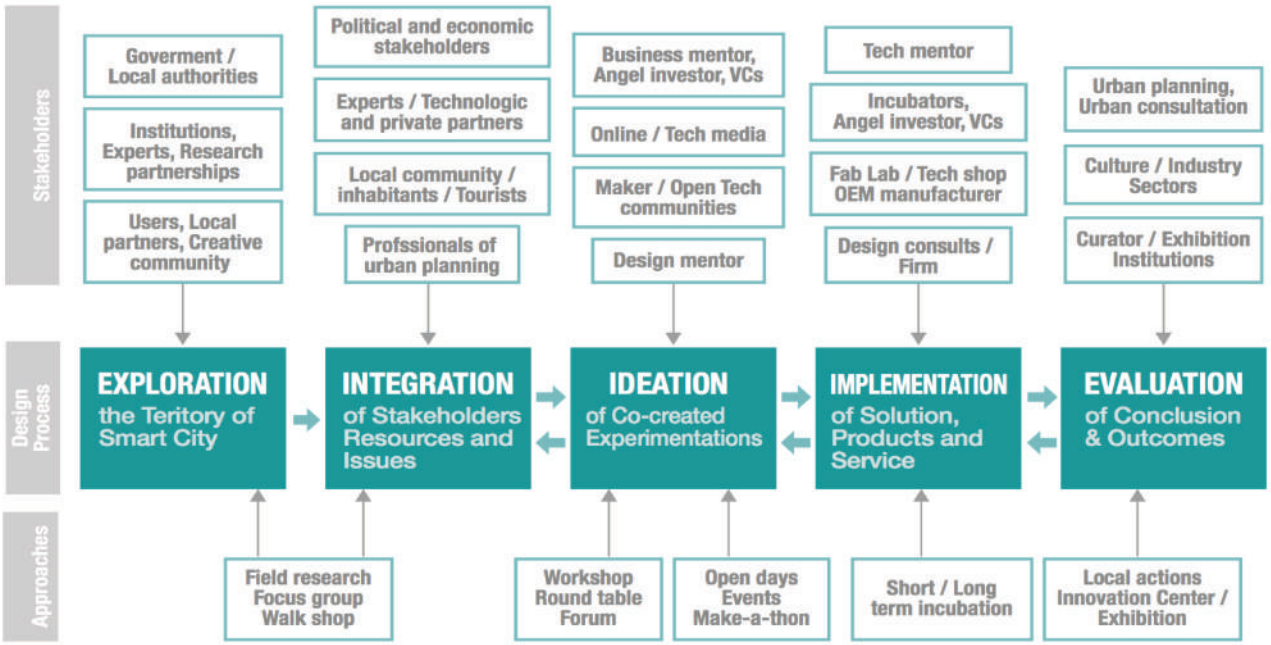

Fig.6 Co-design process

design tools provided by the lab will become assistants to different stakeholders. Helping and supporting them to solve problems in a holistic and local way.

Applying design thinking to open laboratory, we developed a collaborative design process (Fig. 6).[7] Using it as the basis of sustainable humanistic urban short-term planning practice. Connecting the exploration, stakeholders in the field of resources and problems of integration.

As well as the conclusion and the result of evaluation process integrated into a whole. Co-design can contribute to the creativity of designers and untrained designers in the design and development process.[8] Through joint design workshops and focus groups, teams will interact with participants to seek innovative opportunities from a broader perspective and develop viable human-centered city visions and proposals in a conceptual and prototyping manner. The collaborative design practice explores the macro operation mode of a city from a more systematic perspective, while accommodating the perceptions, motivations and actions of individual citizens.

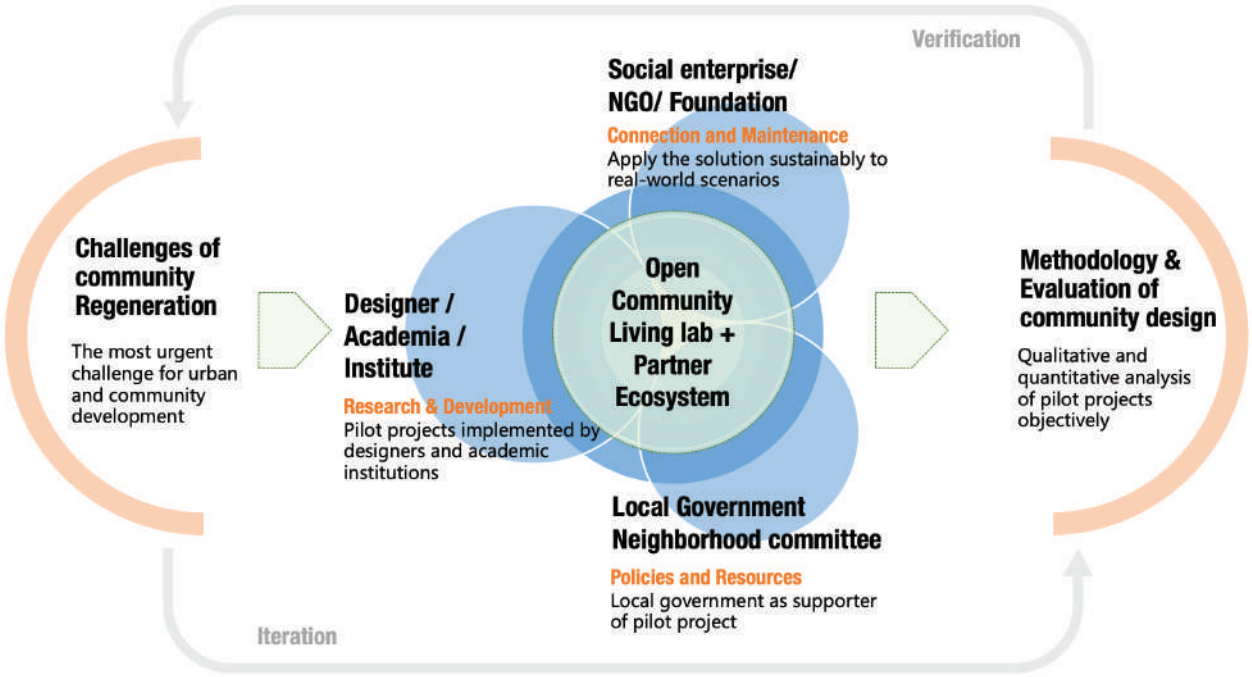

Fig.7 Partner ecosystem

The international collaborative innovation mode of human-oriented city

Aimed at the United Nations sustainable development targets from 2015 to 2030 in a comprehensive way completely solves the development of the three dimensions of social, economic, and environmental problems of the sustainable development path for sustainable objectives and intelligent society construction.

We cooperated with international resources through the organization innovation, knowledge sharing, and innovation for the city to provide intellectual resources and services.

In 2011, the school of fine arts of Tsinghua university cooperated with Parsons to launch the Design Beijing Lab. This explored the practical fields of future smart cities from urban sensing & informatics, urban mobility & social networking, public service & management, and urban OS & Interface. A series of smart city products and services was displayed during the Beijing international

design week from 2012 to 2014. In 2014-2019, Tsinghua university and Stanford university developed series of human city projects (Educational program -based on the Stanford Human Cities Initiative). From the cultural heritage, social justice, economic vitality, environmentally sustainable four aspects to study in this city. In collaboration with the government, the NGOs, and social enterprises in city proper, youth hostel, green areas such as shipping and air pollution information to carry out the sustainable urban development projects. Students have launched the APP of urban accessibility. Pedestrian-friendly urban development is not only an indicator of environmental quality, but also a key determinant of sustainable development. The APP allows citizens to learn about different aspects of street design to improve their walking experience. Encourage users to think critically about the streets they walk on and enable them to come up with useful Suggestions for improving the streets.

The above cooperation fully utilizes the Partner ecosystem (fig.7).[9] Including a number of service design and sustainability studies we conducted with FAO. The direction of service design is the conceptual design and solution of farmers' skill upgrading, agricultural participatory guarantee system, agricultural cultural heritage, Internet agriculture, etc. The project team was composed of interdisciplinary members to ensure the integration of different innovative perspectives. Tsinghua university has conducted in-depth cooperation with FAO and Erlizhuang community to explore the design of environmental improvement, residents' participation and waste recycling with urban agriculture as the link. The above exploration and practice give the advantages to different stakeholders. The grassroots community provides real scenes for the design team. The thinking of FAO provides professional knowledge support for the design team. The model of the partner ecosystem, with Chinese characteristics, produces knowledge and experience. While solving the problem of urban regeneration, contributes to the exploration of the long-term future development direction through iteration and accumulation

Reflection and Conclusion

In humanistic city study, we proposed to create a design framework and successfully launched small-scale projects. Although, the case study is mainly from the teaching experience and course. Relevant exploration is still in the initial stages of project implementation and needs to be combined with specific application scenario city. We have seen the trend and direction of the future. In addition, a deeper understanding of how to improve assessment techniques and how to provide better engagement mechanisms, for the public to contribute their perspectives and

test smarter services and solutions, is needed. This will also provide beneficial reference and support for the practice of urban cooperative design.

In the future, the development of the human city will be confronted with higher challenges in politics, society, management, economy, and other aspects. The goal of co-creating a humanistic city provides designers with the opportunity to enhance citizens' participation from the bottom-up. It also drives the development of design methods and processes. The traditional field of design is expanding in depth and breadth. In terms of "depth", the cross-boundary integration of social humanities and cutting-edge technologies has produced new ideas and new methods. The discipline of design will provide a new paradigm for deeper understandings of human sensibility and social ethics. In terms of "breadth", the field and influence of the design discipline are expanding. From user-centered interaction to a more complex urban and social system. Collaborative innovative design methods are becoming an essential driving force for the sustainable change and development of communities and cities. From the perspective of design-driven innovation, the combination of open and innovative methods and the model of co-creation by partners will better achieve the goal of building a people-oriented city and will bring a preferable future to the public.

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The faster ones don't always win

Dexign Thinking for innovation in urban contexts

Peter Scupelli
Carnegie Mellon University

We live in the Anthropocene Era. Change is exponential. Design and the impact of design is everywhere around us. Human beings are a force shaping the planet's geology, ecosystems, and weather. Our times are often described as volatile, uncertain, complex, and ambiguous (VUCA).

Products and services are developed faster, hold a shorter shelf-life disrupted by new offerings, and exist in the wider environment with existential challenges such as climate change and sustainability. What specific value sets embedded within product and service innovation processes help or hinder the achievement of long-term sustainable development goals?

Rapid change contrasted to relatively stable times, can be confusing and may catch many unprepared. Ways of designing, that until recently worked, are now questioned. While speeding up the development cycle can solve short term problems, rapid prototyping alone does not guarantee alignment with long term goals. Thus, within dynamic and rapidly changing environments where long term goals matter, designers need new paths forward and perspectives to shape sustainable product and service innovations.

Design that considers the complexity of sustainable lifestyles differs from the development products and services that are indifferent to local contexts. For one, societal problems situated in context require multiple perspectives to inform processes. Yet commonly taught human-centered design processes can easily default to a narrow version of customer-centered design that ignores varied contexts and values. Under time pressure, designers' focus can default to customer needs, ignoring the richer perspectives that explore what it means to be human and to lead a meaningful community life.

While it is helpful to consider customer needs and product opportunities, it can be problematic to stop there. The type of Human-Centered Design Thinking that worked in the past to understand customer needs for the design of Human-Computer Interaction (HCI) and services, needs to be adapted when used to accomplish sustainable development goals.

A service design framing allows designers to consider both customer needs and service provider needs. But sustainable lifestyles involve more stakeholders than customer and service provider. One must consider multiple

Much of design education focuses on teaching students to craft products or services that can be made in a short time horizon for immediate release through rapid prototyping or to imagine faraway future concepts uniformed by best practices in the field of Futures Studies

levels of the Socio-Ecological context (e.g., individual, group, organizations, communities, public policy,) and differing value sets.[1]

Tools and methods that allow for different views and perspectives where innovation is grounded, afford designers finding new opportunities for economic development. In other words, new ways of looking at problems can provide solutions to previously ignored problems and new opportunities for development.

To illustrate the point, next is a simple example from HCI for sustainable behavior change. The perception and framing of problem determine the solution space. HCI solutions that frame the problem at the individual level, often determine persuasive technology (i.e., knowledge gaps, triggers, motivation;)[2] with solutions such as mobile apps and gadgets that count steps, biometrics, and log calories, send reminders, and so forth. But, easy to measure metrics often provide mixed results when other critical contextual variables are not considered.[3]

What can be done to find more effective solutions for sustainable behavior change related to health choices and sustainability? How might Human-Centered Design Thinking applied to lifestyle choices be augmented? Two suggestions emerge from the public health literature with regards to behavior change the: Socio-Ecological Framework and Stages of Change Model.

First, the Socio-Ecological Framework states that health decisions are made within a broad context shaped by five layers: individuals, groups, organizations, community, and public

policy. Successful past public health initiatives operated on multiple levels of the Socio-Ecological framework (e.g., smoking, drunk driving). The broader framing and evidence-based approach opens up the behavior change design space strategically to include family, groups, organizations, community, and public policy. Such a framing shifts the context to support sustained behavior change efforts.

Second, people differ. One size does not fit all. Design solutions for behavior change and personal transformations should consider different stages and time processes.[4] The Stages of Change model suggests that depending on where people are in the transformation process, different interventions are needed.[5] Behavior change is a process and requires a theory of change that specifically supports human transformation in a sustainable manner.

For design tools and methods to be helpful, they need to be appropriate to the task and context. Both the Socio-Ecological framework and the Stages of Change model provide powerful scaffolds for design led innovation when used in conjunction with Human-Centered Design Thinking. What does the example from sustainable behavior change tell us about sustainable development in urban areas?

Desirable futures in sustainable urban areas hinge on two transitions: increases in urban populations and need to rapidly decarbonize urban lifestyles. The first transition involves the increased numbers of urban populations. Currently more than half of people live in urban areas. By year 2050, two out of three people are expected to live in urban environments.

The second transition, to avoid the most catastrophic effects of Climate Change, requires net carbon emissions to be reduced by at least 50% by year 2030 and 100% by year 2050.

Decarbonized urban lifestyles present an incredible design opportunity for innovative products and services.

What does sustainable urban growth and climate adaptation look like? How might Human- Centered Design Thinking be augmented to meaningfully engage with such challenges? In this short article I describe how the field of Futures Studies methods can augment Human Centered Design Thinking to focus on challenges, opportunities, and design methods that support creating innovative products and service for sustainable development.

There are five challenges for designers wanting to create innovative products and services for sustainable development in urban centers: (a) design for sustainable values and cultures, (b) align short action with long term goals, (c) align design with forces of change, (d) diversify innovation pipeline by time horizons, and (e) consider alternative futures.

Design for sustainable values and cultures. Values and cultures matter. Unfortunately, values are not explicitly explored through current Human-Centered Design Thinking methods. Value is created by design; values

Figure 1. Screen capture of Sohail Inayatullah explaining Causal Layered Analysis at TEDx.

and biases are embedded into design processes and values drive design. Therefore, there are ethical implications that designers must consider.[6] In short, technologies are not neutral; negative unintended consequences are to be considered.[7] Anticipating unintended consequences of designed products and services is increasingly important, and the need to proceed ethically is increasingly acknowledged as a priority.[8] Furthermore, designers must broadly consider the environmental implications for designed products.[9] Consequently, the question of how to critically engage values in design processes is an important topic for designers and design methods. How do values drive design decisions, how are values part of design processes, and how can design outcomes be evaluated? Futures Thinking methods such as Causal Layered Analysis can help designers to notice the connections between values, worldviews, systems, and everyday behavior, (Figure 1).[10,11]

Align short term action with long term vision goals.

Challenges such as innovation for societal-level sustainability require new thought, temporalities, and action. Human Centered Design Thinking tends to focus on the present problems at hand on a short time horizon. Instead, sustainable development goals and rapid decarbonization to avert the climate catastrophe are on a year 2030 timeline. There is a tension between ever shortening design product cycles and long- term thinking required by sustainable development. Examples of the shortening of timescales in design industries include fast fashion,[12] continuous beta,[13] and lean start-up.[14] Contrasted to the short-term thinking in design, plans for societal- level sustainability are on long horizons, such as 2050 or even 2100.[15,16] Design for sustainable change requires aligning short-term design actions to long-term visions.

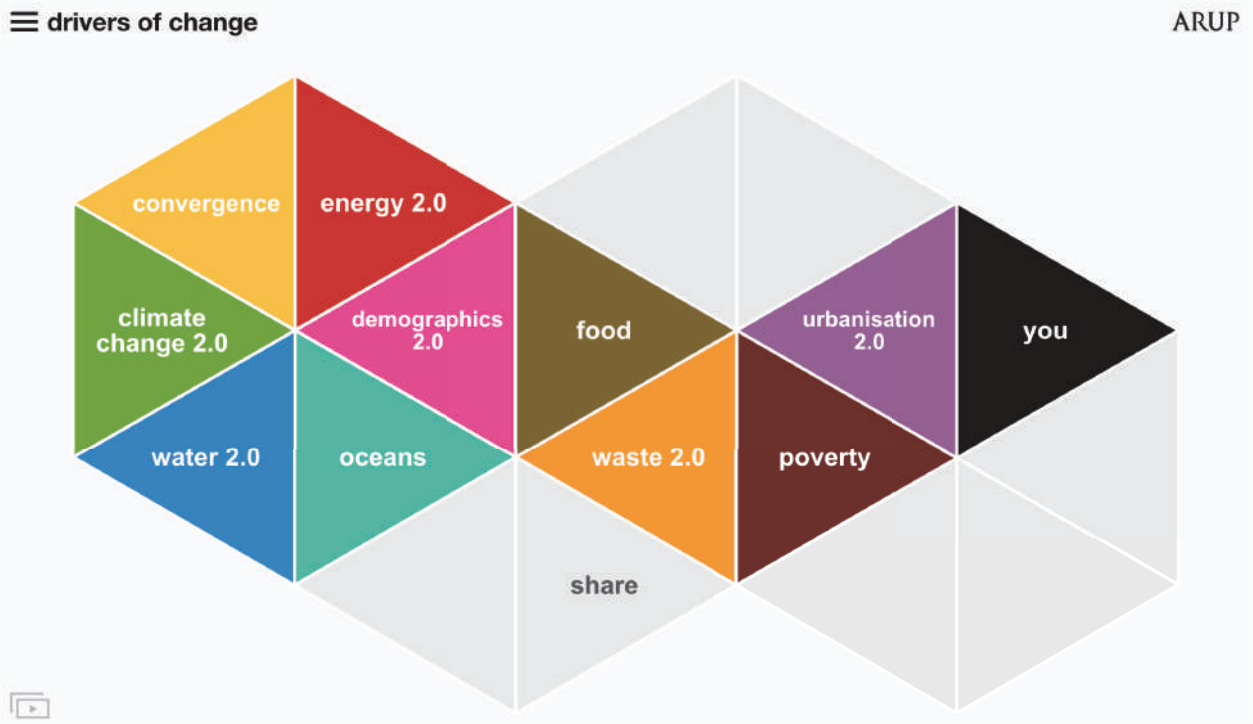

Figure 2. Screen capture of the ARUP drivers of change app http://www.driversofchange.com/

Align designs with forces that shape change.

The urban context is shaped by multiple forces ranging from social, technological, economic, and environmental to political (STEEP) forces.[17] Designers that focus mostly on technological push and Human-Centered Design in an urban context can miss other key factors for success. We live in volatile, ambiguous, complex, and uncertain times where it is increasingly difficult to anticipate the valuable innovative products, services, and experiences to design for sustainable urban development. The far future, in a dynamically changing world, is impossible to predict, but there are systematic ways of imagining it. When designers consider how design solutions align with current and future STEEP forces solutions are more robust and resilient (Figure 2).

Diversify innovation pipeline by time horizons.

Unfortunately, there are no single design solution that can magically solve complex problems such as sustainable development. Therefore, designers should explore a diversified portfolio of designs for multiple time horizons (Figure 3). There are multiple

time horizons to consider when strategically managing an innovation portfolio through the three horizons framework.[18] For example, for large technology companies such as Microsoft, designed products might be conceived for three different timescales ranging from three months to three and seven years. The types of design methods that are appropriate for each time horizon differ. Yet, much of design education focuses on teaching students to craft products or services that can be made in a short time horizon for immediate release through rapid prototyping or to imagine faraway future concepts uniformed by best practices in the field of Futures Studies. The key question for designers to consider is how might their short term making be aligned with long term vision goals? Furthermore, how might a focused portfolio of design explorations on multiple time horizons together lead to desirable long-term goals?

Consider alternative futures.

Designers usually explore multiple ideas but then focus on developing one single project direction. Focusing on only one product makes practical sense, but it is a risky strategy when we live in turbulent times and change is exponential. Nobody can predict the future with much accuracy. Designers can learn from some of the core ideas from Futures Studies. Such as "the future" does not exist because it has yet to happen. There is no such thing as "the future" out there that we are singularly headed towards; there are always multiple possible alternative images of futures.[20] Choices made in the present time make some futures more or less likely.

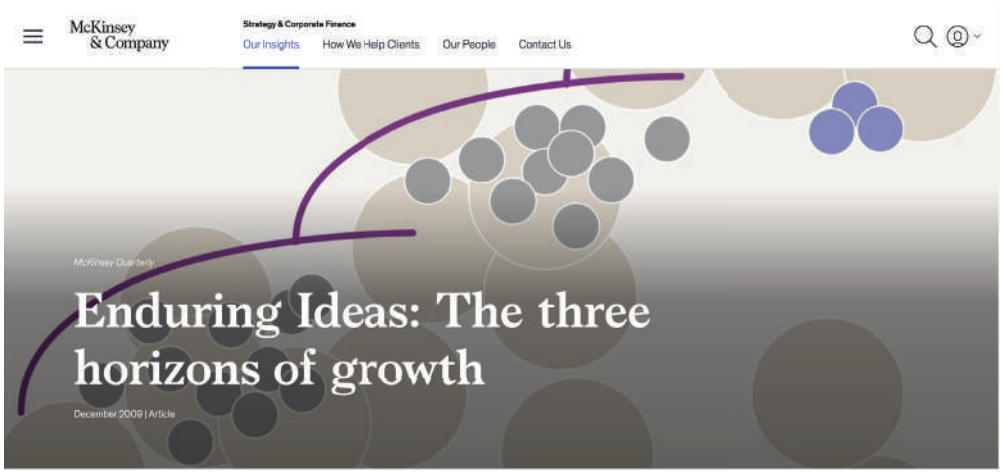

Figure 3. Screencapture of 2009 article from McKinsey & Company on the three horizons of growth[19]

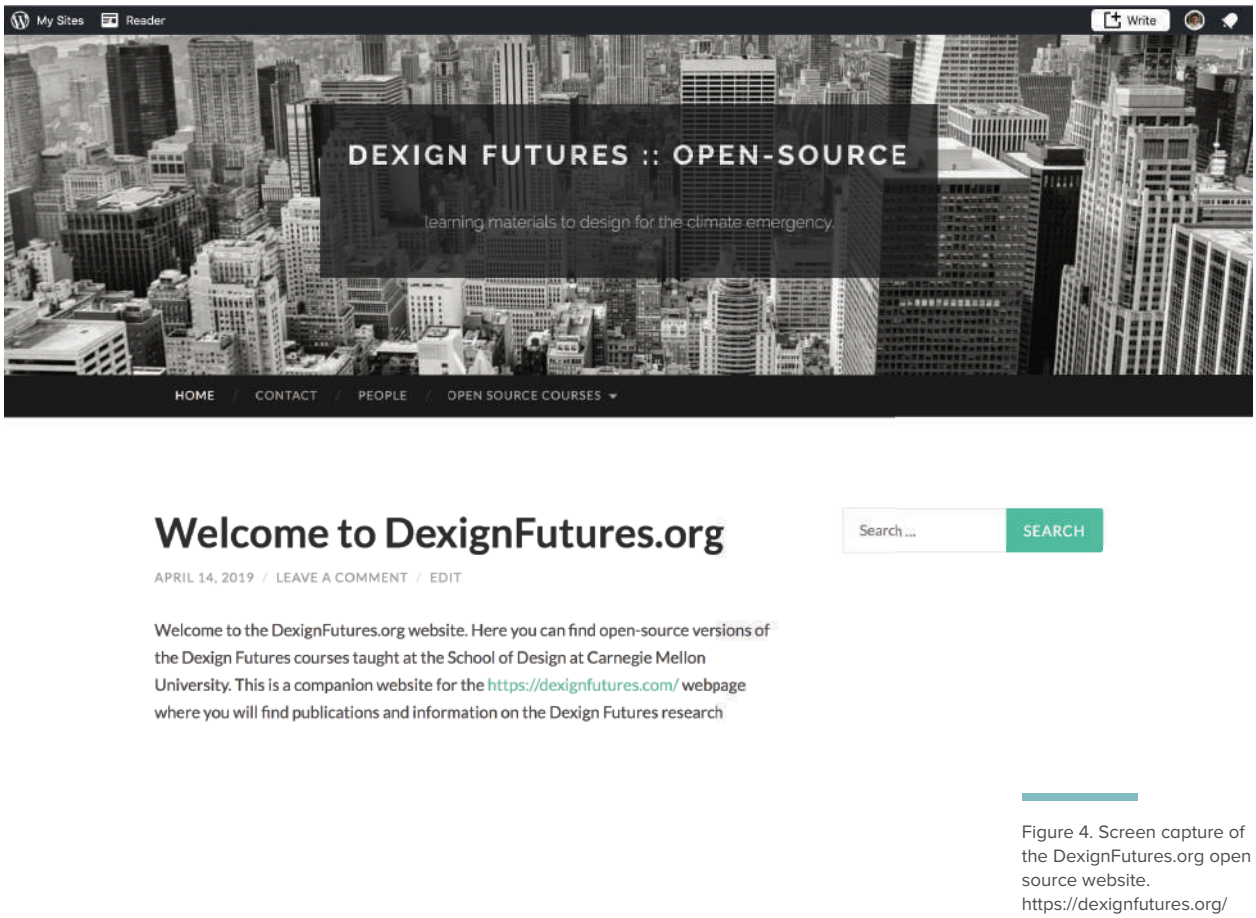

Figure 4. Screen capture of the DexignFutures.org open source website. https://dexignfutures.org/

Although some images of possible futures are more likely than others, in times characterized by dynamic change, it is difficult to accurately predict what will happen. From a design perspective, if one explores and prepares for alternative futures designed products and services will be much better equipped to overcome challenges when they do arise. Resilience is often a result of robust exploration of alternative futures.

The challenges and opportunities described above are supported by new design methods which I refer to as Dexign Futures or Dexign Thinking. The "X" in Dexign was originated by Arnold Wasserman to signify an experimental form of design and design education.[21]

Dexign Futures combines human-centered design thinking with futures thinking to align near term design action with long range vision goals – while navigating uncertainty and accelerating innovation toward desired futures.[23,24,25,26,27]

Dexign Futures includes a set of methods explicitly focused on aligning near-term design action with sustainable futures. All the methods described above are available as open-source materials, go to https://dexignfutures.org (Figure 4). The current versions of course materials are being tested at Tsinghua University in Beijing, China; Politecnico di Milano, Italy; and Georgia Tech University in USA.

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How to achieve sustainable urban development and shared prosperity?

In his book Fifty Inventions That Shaped the Modern Economy, one of the well-known contemporary economists, Tim Harford put it in this way: “What you have to wait for maturity is not just a technology but a system.” He describes a story in the book that Faraday discovered Electromagnetic Induction in 1830, and Edison invented a series of electric solutions in 1870, such as Electric Lamp and Generator, but these did not really enter the industrial field until 1890s, about 20 years later. In other words, all the relevant pricing system of charging equipment became mature in 1920. After 5 decades, the ability for people to use electricity came into the proliferation stage.[1] When it comes to urban sector, the application of innovative technologies also requires the structure design of sustainable business models and investment, such as utilization of 5G, autonomous driving and artificial intelligence. To find the balance of business model serves as the foundation when technology can be sustainably and widely used.

Climate change and resource scarcity have been the globe concern, hence cities need to undertake more responsibility to drive the changes with technology like artificial intelligence and alternative data. The introduction of sustainable finance and ESG investment will not only become a powerful weapon for asset management institutes to avoid risks and discover investment signals, but also turns to be turning point to accelerate the global advocacy of sustainable consumption and balance development and resource utilization. Technology has no nationality and no colour, but launch a green competition for global players to pursue sustainable investment.

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SECTION 4

URBAN BUSINESS MODELS AND SUSTAINABLE FINANCE

Development Banks make greener cities

Unleashing the potential of Sustainable Finance: How Development Finance Institutions can fill the climate resilient urban infrastructure gap

Jiajun Xu and Xinyue Wu
Institute of New Structural Economics at Peking University

The world is facing the dual challenge of closing a vast urban infrastructure financing gap and making urban infrastructure more climate resilient. As estimated by the OECD, USD 95 trillion will be required to develop transport, energy, water, and telecoms from 2016 to 2030 in developing countries.[1] With the temperature rise, the extreme weather will have direct physical harm on infrastructure as the aging infrastructures would be vulnerable to storm surges and sea level rise. In order to keep global temperature rise this century well below 2 degrees Celsius above pre-industrial levels, an additional 10% of investment will be needed to develop climate resilient infrastructure, adding to the USD 6.9 trillion needed per year by 2030.[2]

Limitations of available financing options

Yet the existing financing options, such as fiscal support, capital markets, and commercial banking, have played a limited role in taking up the above dual challenges. The urban infrastructure investment project incurs high upfront costs and long-term investment cycles that entail uncertainties and risks, which discourage profit-driven commercial banks and short-termism capital markets from financing these projects.[3] In addition, capital markets in developing countries are often at such a nascent stage that they are not ready to provide long-term finance. The positive externality of climate resilient infrastructure leads the government to take a greater stake in financing the public goods of urban infrastructure projects with local tax revenues and intergovernmental transfer. However, for most developing countries, the fiscal support is limited because of the less desirable economic performance and the lack of effective enforcement mechanism on tax collection.[4]

While innovative financing solutions have been attempted to support climate resilient urban infrastructure, the scale of these attempts are often too small to fill the vast financing gap. Such attempts usually rely on market mechanisms such as the green bond, climate resilient bond and catastrophe bond. But their scale is relatively limited: Globally, as is reported by climate bonds initiative, the

254.9 billion USD

amount of the green bond issued in 2019

issuance of green bond in 2019 was around USD 254.9 billion, mostly from developed countries, with the top five issuers including the US, France, China, Germany and Netherland for the period from January to September of 2019. These countries are also the top five in terms of cumulative issuance.[5,6]

Unleashing the potential of DFIs for financing climate-resilient urban infrastructure

Development finance institutions (DFIs) are uniquely positioned to financing climate resilient urban infrastructure. DFIs are supported and founded by governments with an official mandate of fulfilling public policy objectives. The institute of New Structural Economics at Peking University is building a database on DFIs worldwide, which has witnessed a renaissance of DFIs worldwide as there has been increased recognition from the international community on the role of DFIs in tackling development challenges and making

impact investment to mitigate climate change related risks.[7] Apart from the newly established MDBs initiated by developing countries, such as the Asian Infrastructure Investment Bank and New Development Bank, both developed countries and developing countries are establishing national development banks to meet development challenges.

The primary rationale for establishing DFIs is to fix market failures such as information asymmetries, positive externalities, pro-cyclical behaviors of private banks, and short-termism of capital markets. With the mission of providing long-term finance equipped by long-term liabilities, DFIs are expected to overcome the maturity mismatch from which most commercial banks suffer.[8]

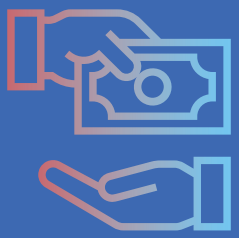
Apart from fixing market failures, DFIs can play a role of incubating markets which may not exist otherwise. Unlike in developed countries with well-established market economies, market institutions in developing and transition economies are either flawed or nonexistent. Without well-functioning market institutions, markets cannot efficiently fulfill many of their functions, such as allocating resources. For example, corporate governance is generally weak and contract enforcement is unreliable in developing and transition economies.

Below we will briefly summarize three case studies to illustrate the role of DFIs in financing urban infrastructure and making it more climate resilient.

Case Study 1: China Development Bank incubates the urban infrastructure market for China.

China was urbanizing at a breakneck speed in the late 1990s as it was accelerating its pace of industrialization. The potential for rapid large-scale urbanization was huge in China. In 1998 the urbanization rate in mainland China was merely 30.4%, compared with the world average of 46% and 80% in developed countries.[9] Given its total population of more than 1 billion, the scale of China's urbanization would be unprecedented and would create vast demand for urban infrastructure investments.

Despite the huge demand for urban infrastructure financing, alternative sources of funding failed to take up the challenge: Commercial banks were reluctant to finance high upfront costs or large-scale and long-term projects, especially given maturity mismatch and high risks in the uncharted areas; long-term bond market was underdeveloped with little checks and balances to ensure local governments could repay their debts in the long run; and the fiscal capacity of municipal governments was too weak to fill the financing gap. In addition, the scarcity of fiscal revenues was severely exacerbated by the first budget law issued in 1994, which cut local governments off from direct borrowing and forbade them from running deficits or selling bonds.



Both developed countries and developing countries are establishing national development banks to meet development challenges.

CDB has successfully incubated the market for financing urban infrastructures, which can be illustrated by the Wuhu model.[10] Wuhu is a city in the Anhui Province, located in the middle of China. The cooperation agreement was signed by CDB and the Wuhu municipal government in August 1998.

At the heart of the CDB's efforts was leveraging financing to incubate markets for long-term infrastructure finance, enhancing creditworthiness, and building and improving market institutions in order to provide long-term finance.[11] The role of CDB is not simply limited to the provision of long-term finance; more importantly, CDB helps to incubate markets to the point of maturity where it can exit and allow market players to then play the full role.[12] The process of incubating markets involves three phases: advancement of professional planning in line with government priorities, CDB incubation, and market participation.

At the first stage of project preparation and selection, CDB worked closely with the Wuhu municipal government to prioritize development projects to which local governments are committed. During this process, advance planning by professionals at CDB played a key role in ensuring the alignment of projects with development priorities and avoiding duplication of efforts and debt-overburden of the local government.

At the second stage, CDB plays a key role in incubating markets that do not exist before its intervention. CDB first assisted the local government and related departments in jointly incorporating a new project company as an eligible borrower in the market: The Wuhu Construction Investment Corporation Limited (WCIC), a local government financing vehicle (LGFV), was incorporated in February 1998. When conditions allowed, the project company was restructured to align its governance structure with modern enterprise practices. The borrower's revenue generation

methods were designed or improved—including cash flow, gains on increased land value, and other proceeds that cover principal and interest on the loan to the project company. CDB increased the credit standing of borrowers by utilizing the creditworthiness of local governments where possible. To remain a positive cash flow, a portfolio of infrastructure projects with difference levels of return were bundled together so that the financial sustainability of WCIC was ensured. By drawing on the model of the World Bank's lending in mainland China, CDB loans to the WCIC had to be guaranteed by the local government. Initially, the Wuhu municipal government used fiscal revenue to set up a repayment fund account in December 1998. Later on in 2002, CDB facilitated the local government to undertake the reform of land bidding and auction so that the WCIC could use revenues from land sales as the collateral. It was further guaranteed by the legal approval of the Wuhu Municipal Congress that fiscal revenues would serve as the last resort if the borrower failed to repay its debts.[13]

At the third stage, CDB focused on designing market participation by attracting more capital from commercial banks and capital markets. To achieve market incubation, CDB worked with the local government to design different modes of market participation according to the profitability of projects and market practices, such as organizing syndicated loans and channeling funds from commercial banks. Moreover, CDB facilitated bond issuing of the borrowing company and encouraged equity investments. It was reported that CDB accounted for 100% of WCIC's borrowing in 1998 when the project just started, but after 10 years of market incubation, only 26% of lending to WCIC was supported by CDB and the rest was from the market. This shows the success of market incubation and a commercially viable model for urban infrastructure development.[14]

The case of CDB has revealed the general implications for development banks in incubating markets compared with simply fixing market failures, but it possesses some unique Chinese characteristics that have enabled the specific model of market incubation. First, state ownership of land enables the state-owned LGFV to use revenues from land scales as the collateral in order to mitigate risks of the pilot CDB's lending. Second, the Chinese local governments have relatively strong capacity in mobilizing financial resources which may not be the case in some developing countries with low state capacity.

Case Study 2: Green investment banks finance climate resilient infrastructure

To tackle with the climate issues for sustainable urban development, 13 green investment banks (GIBs) have been created by governments to finance green infrastructure by 2015.[15] As shown in Figure 1, most GIBs are located in developed countries, such as in the UK, the US, Australia, Japan, and Switzerland. Meanwhile, there are newly built subsidiaries of DFIs, such as FinDev Canada, formed in 2018, as a subsidiary fully owned by the

Figure 1: Green Investment Banks in the World
© OECD, 2015, Green Investment Banks: Leveraging Innovative Public Finance to Scale Up Low-carbon Investment, Policy Perspectives, p. 6.

export credit agency of Canada that includes building a low carbon future, renewable energies, and green growth as priority sectors for its business operation.

From the new structural economics perspective – i.e., financial arrangements need to meet divergent needs of the real economy at different stages of development, GIBs can remove binding constrains to draw in private capitals and to scale up infrastructure financing by creating enabling conditions for climate resilient investment. According to the OECD, GIBs normally have a smaller size than NDBs in a country and run on a financially sustainable basis. The function of the GIBs is to be a game changer on accelerating the transition from a carbon-intensive to a low carbon and climate resilient development path.[16] The Institute of New Structural Economics at Peking University plans to track the role of DFIs in tackling the challenge of climate change as part of the systematic effort of building the first comprehensive database on DFIs worldwide.

Case Study 3: The case of BNDES and DBSA in scaling up climate resilient infrastructure financing

Apart from establishing new GIBs, some existing DFIs have stepped up their efforts to finance climate resilient infrastructure. Banco Nacional de Desenvolvimento Econômico e Social (BNDES) and Development Bank of Southern Africa (DBSA), state-backed national development banks in Brazil and South Africa respectively, are critical actors for facilitating their nation's goal in achieving National Determined Contributions (NDC) in line with the Paris Agreement and in building low carbon, climate resilient infrastructure. Electricity has been cut off in Brazil because of the extreme weather conditions that drought has caused reduced water supply for the hydropower stations, making the power sector vulnerable; for South Africa, power is mostly coal fired and the country is vulnerable to sea level increase as well as droughts.[17]

According to an OECD study in 2019, with a strong will in shaping a climate resilient future, both BNDS and DBSA have strategically targeted the mobilization and scaling up of other financing resources into climate resilient infrastructures. The repositioning from the provider of patient capital to a catalyzer for attracting other financing resources can be demonstrated by the Green Climate Fund of the DBSA, where blended financing is provided to improve the risk-return conditions of infrastructure projects to be more commercially viable.[18] For BNDES, it has incubated the international market for Brazilian green bond. In 2017, BNDES, as the first mover, was the number one case of Brazilian banks issuing international green bond, valued USD 1 billion on Luxembourg Green Exchange, augmenting the potentials of Brazil's green finance capital market in the future.[19]

Conclusions and policy recommendations

The world is witnessing the dual challenge of filling the financing gap of urban infrastructure development and enabling urban infrastructure to contribute to the right trajectory of a climate resilient future. The current financing arrangements available provide limited support for filling the gap. DFIs can be a significant policy tool for supporting policy goals on low-carbon and climate resilient development. In particular, they are significant in drawing in other financing resources and incubating financing market that may not exist otherwise. To unleash the potential of DFIs in filling the gap for climate resilient urban infrastructure, it is of paramount importance to ensure that DFIs are well designed and professionally managed to avoid the historical mistake of political capture. Going forward, we call for more academically rigorous studies to explore how to make DFIs work more effectively to finance resilient urban infrastructure, which way is more appropriate as far as country circumstances are concerned – either the establishment of new specialized GIBs or the mainstreaming of climate finance in the existing DFIs, and how to create synergies among different layers of DFIs at subnational, national, regional and global levels.

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AI could be environmentally friendly?

Senseable Economics: Sustainable Finance and ESG Investment embrace artificial intelligence and alternative data

WeBank AI Department Moonshot Team

Foreword

"Climate Casino" and Sustainable Economic Growth

In the BBC documentary "seven worlds, one planet", a film crew member filming in Antarctica tells an interview that it is "too hot here". After witnessing the effects of climate change, he burst into tears thinking about the forthcoming fate of these animals. Other 2019 BBC documentaries: Climate change: the facts, revealed that we are facing the biggest threat for thousands of years -- Climate change, stronger snowstorms, faster floods, stronger heat waves, faster sea level rise... Climate change is causing far more extreme weather than expected, a storm that will engulf all of humanity.

How serious is climate change? On the one hand, this topic is being reported more and more seriously and urgently; on the other hand, people are so used to such reports that they think there is a way out and put the "alarm" on the shelf.

Climate Central's study, published in Nature Communications, uses neural networks and Digital Elevation Model (DEM) for satellite to predict that by 2050 rising sea levels will affect more than three times as many people as previously predicted, with about 360 million people threatened by flooding and of which about 150 million will live on land below sea level. By 2100, the number of people affected by rising sea levels will have climbed to 360 million. Behind the eye-opening numbers, the effects of rising sea levels due to climate change are still unfolding. The overwhelming evidence suggests that entire ecosystems are teetering on thin ice in the face of all this, and that the global economy will end up paying the bill.

The 2018 Nobel Prize for economics went to Paul M. Romer and William D. Nordhaus. Owing to Paul's contribution to the key role of knowledge and technological progress leading to economic growth, endogenous economic growth model is established; the other incorporates climate change into the Macro Economic analysis, studies the interaction between environment and economy, and describes the catastrophic

South Pole
© **BBC documentary**
"seven worlds, one planet"

price brought by human ignorance and inaction. In his new book, "the Climate Casino: the Risks, Uncertainties and Economics of Global Warming," Nordhaus likens the tipping point of climate change to the point where we are entering a casino where human behaviour is rolling the global warming dice, but there is still time to fully change and come out.

On the 50th anniversary of the Nobel Prize in economics, these two experts' theories answer one of the most fundamental and urgent questions of our time -- how to create long-term sustainable economic growth. This is the entry point of our research: how to promote sustainable finance and investment through the application of artificial intelligence and big data, so as to achieve the balance between economic growth and sustainable development.

As small as human beings are in the face of nature, the boundary of technology lies there. From the Kyoto protocol to the Paris agreement, which covers nearly 200 countries, to the annual conference of the parties to the United Nations framework convention on climate change (UNFCCC), we are fortunate that we have been acting, and technology is our most powerful weapon in our fight against nature.

Chapter One of Trends

Global Trends in Sustainable Finance and Investment

Sustainable finance and investment have become a global consensus for sustainable development.

In June 2019, the European Commission technical expert group released EU Sustainable Financial Classification Scheme which defines sustainable finance to promote the realization of six environmental objectives of green economic activities, including: climate change mitigation, climate change adaptation, oceans and sustainable utilization of water resources and protection, recycling economy, waste treatment and recycling, pollution prevention and control, the protection of the health of the ecosystem, etc. According to the latest figures from the Global Sustainable Investment Alliance (GSIA), sustainable finance accounts for 52.6 percent of the EU's portfolio and 21.6 percent of North America's.

According to the Global Responsible Investment Review 2018 by the Global Sustainable Investment Alliance, the total amount of professional asset management based on the concept of responsible investment in the world's major economies reached US $30.68 trillion in 2018, achieving an increase of 34% over 2016 and accounting for 33% of the industry's assets under management. According to the World Investment Report 2019 released by the United Nations Conference on Trade and Development in June 2019, to advance the achievement of the United Nations 2030 agenda, developing countries alone face an annual funding gap of US $2.5 trillion and must mobilize mainstream financial institutions to join. Sustainable development calls for sustainable financial input.

Three trends in sustainable finance

1. Public-private partnerships, regulatory and international institutions set the stage and standards, and investment and financial institutions respond positively.

Since 2006, the United Nations Principles for Responsible Investment (UNPRI) was established, so far, more than 60 countries around the world have joined the UNPRI organization of more than 2700 institutions, more than 450 member institutions asset management agencies, including the world famous pensions, sovereign funds, and insurance institutions, such that management of assets total more than $82 trillion.

In December 2015, the G20 Financial Stability Committee initiated the working group on Task Force on Climate-related Financial Disclosures (TCFD), the first international initiative to look at climate change from a financial stability perspective. More than 100 companies have made public commitments to join, with a total market value of more than $3.5 trillion, including about $25 trillion in assets managed by financial institutions.

At the end of 2017, Central Banks and regulators in eight economies, including

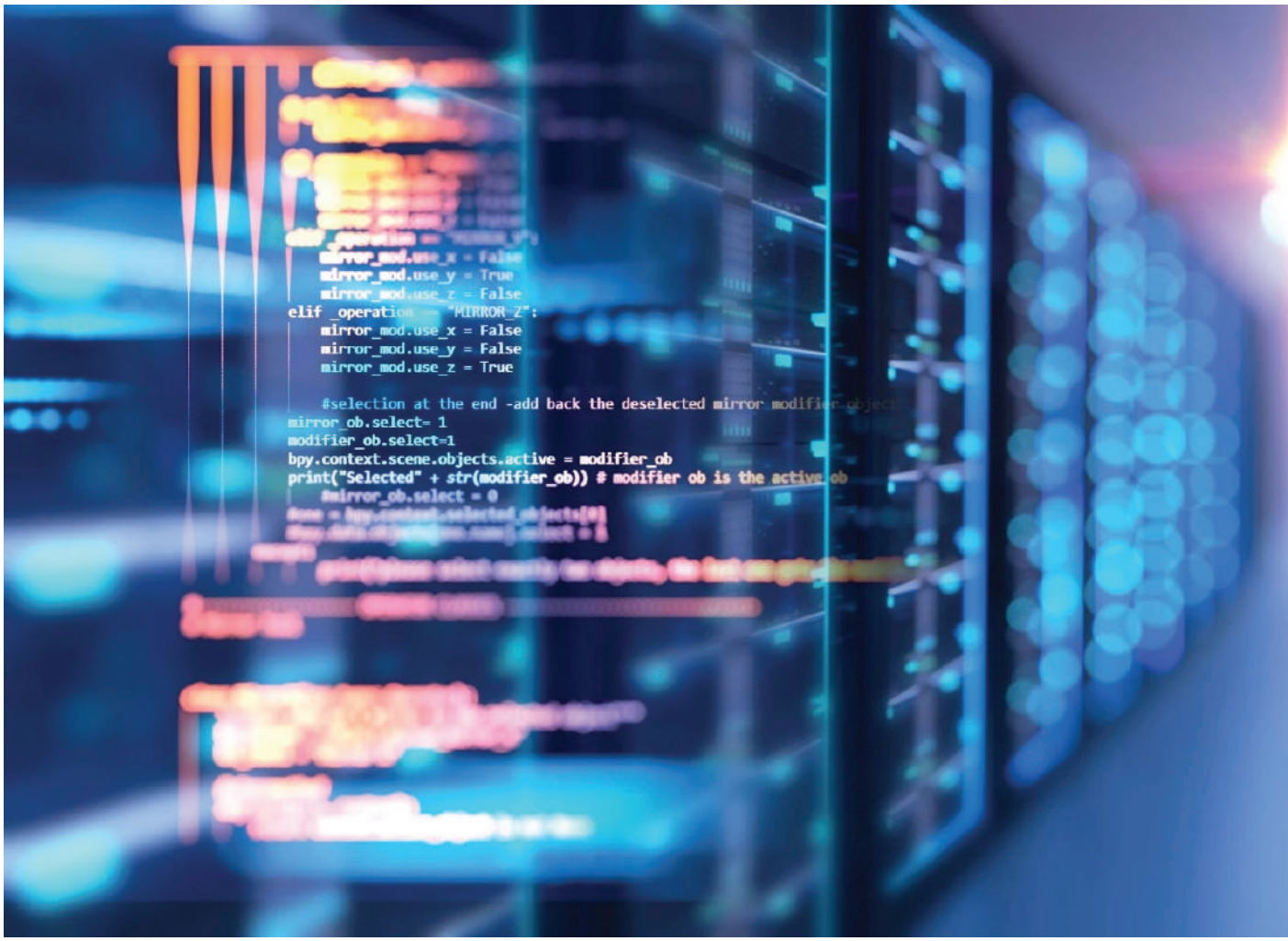
Developing countries alone face an annual funding gap of US $2.5 trillion and must mobilize mainstream financial institutions to join.

Sustainable development calls for sustainable financial input.

China and France, launched the Network on Greening the Financial System (NGFS), which aims to promote the disclosure of environmental information by financial institutions, to conduct environmental risk analysis, and to strongly support green investment and financing. By April 2019, the network had grown to 36 member countries.

In December 2019, the European Commission released the European Green Deal, a blockbuster policy aimed at halting climate change by shifting to clean energy and a circular economy, thereby increasing resource efficiency and restoring biodiversity. The agreement will establish a €100bn "Just Transition Mechanism" and urge European countries to set up a broad national tax reform Mechanism, with "climate taxes" as the focus.

On December 6, 2019, the European Banking Authority (EBA) released the sustainable finance action plan which formally integrates ESG risk factors into the financial sustainability assessment system and draws a roadmap for sustainable finance action in Europe in the next five years in three dimensions: strategy and risk management, information disclosure, and scenario analysis and stress testing.



2. ESG becomes an effective means of implementing sustainable finance and investment

As the core non-financial indicators, environmental, social, and corporate governance (ESG) factors will not only become the key indicators to measure the sustainable development ability and potential of enterprises, but also become an important feedback mechanism for the high-quality development of sustainable finance. Take China as an example. In September 2018, the China Securities Regulatory Commission (CSRC) officially issued the revised code of governance for listed companies, strengthening the leading role of listed companies in environmental protection and social responsibility and establishing the basic framework of environmental, social responsibility, and corporate governance (ESG) information disclosure.

3.Technology helps quantify and evaluate sustainable finance

In 2018, United Nations Development Programme (UNDP) launched the Sustainable Development Goals (SDGs) impact platform to provide data-driven and investor-driven market insights; matching services and impacting due diligence for investors who wish to advance the SDGS process in their portfolios. The European Banking Authority's

(EBA) sustainable finance action plan, published in 2019, also proposes to quantify the degree to which capital gains are affected by climate-related environmental risks by developing special climate change stress test models.

Chapter Two of Technology

Applications of Artificial Intelligence Technology in Sustainable Investment

Although the application of new technologies represented by artificial intelligence in sustainable investment is still a "new-born" in the field of large capital management, the application of artificial intelligence and alternative data has long been adopted, providing mature and reusable experience in the field of sustainable investment and green finance.

The power of AI and Alternative Data

Throughout the field of international asset management, top-tier asset management firms Blackrock, Vanguard, JPMorgan Chase, Morgan Stanley and others have already invested heavily in the application of capital management technology and alternative data. Launched in 2017, JPMorgan Chase's "Big Data and AI Strategies" special reports and machine learning makes the analysis of large-scale, unstructured Data sets possible. It also builds a trading strategy, emphasizes to build "ecosystem" Big Data, makes possible the integration of large Data sets and alternative Data sets, including personal Data generated (social media, product reviews, Internet search trends, etc.), business process Data generated (commercial transactions, credit card Data, orders, etc.) and machine generated Data (satellite image Data, the trajectory Data and ship's position, etc.). Similarly, Blackrock in 2017, formulating a fundamental active equities and active stock units for active investment department, used the quantitative methods such as AI in active investment management, established an AI lab in 2018, and published "Tech 2020 plan." 2018 technical contribution to the cash income reached US $790 million, covering 6% of its revenue.

In June 2019, Liao Li, Executive Vice Dean of the PBC School of Finance of Tsinghua University, delivered the keynote speech, "the Rise of Alternative Data", emphasizing the three characteristics of alternative data. First was its large volume reflecting on its scale and amount of transmission. Second, he emphasized the high flow speed, real-time or near real-time data acquisition and transmission; Third, he highlighted the many types and various forms of data structure. In December 2019, MIT professor Robert Pozen et al. also wrote an article in the Harvard Business Review, highlighting the value of machine learning and alternative data in asset management, such as the ability to predict crop yields in China by monitoring satellite images in real time, and the use of GPS and other data to track retail store traffic.

In the "Global Asset Management Report 2019," BCG elaborated the viewpoint that

technology leads asset management institutions, elaborated data and analysis change the competitive landscape, and illustrated the role of news and public opinion, web data, satellite remote sensing images, credit card data, and other data in monitoring risks and ESG indicators. The institutions will be able to gain benefits through high-quality information. In its Asset Management Industry Report 2019, Ernst & Young also listed big data and artificial intelligence as one of the four trends, highlighting their applications in investment research and investment decision-making. According to its data, 14 hedge funds using AI and machine learning technology have outperformed traditional hedge funds by 100 percent over the past decade. Already, 78% of the world's mainstream asset management companies are using or will use alternative data (such as online retail data, social media data, satellite data, etc.), spending more than 2.5 million yuan per company.

"Senseable Economics" and Sustainable Investment

In the era of large capital management, it is also a natural trend for capital management institutions and technical forces to go together to implement sustainable investment. As China and other markets become more open, asset management will gradually be brought into line with international standards. At the same time, the breakthrough of asset management scale accelerates the technological process of asset management. Before this comprehensive examination of the ability to find high-quality investment targets, investment research ability and risk pricing ability, the establishment of strong, comprehensive and real-time underlying data capabilities combined with AI computing power will become a collective battle for sustainable investment institutions and technology companies.

Can a picture of the brightness of city lights at night analyse the economic index of a region? Can a picture of a field crop be used to predict an agrometeorological disaster? This is not a myth in perceptive economics. WeBank AI Scientist Haishan Wu initiated Senseable Economics, which refers to the use of artificial intelligence technology to mine sensor's big data and to realize real-time perception, quantification, and prediction of economic systems This is to provide decision-making methodology for some major sociological and economic problems.

Currently, the proliferation of new sensors and 5G technology, combined with the successful development of microsatellites, has produced a vast amount of spatiotemporal data, providing a new way to assess the development of sustainable investment.

Within the case of WeBank using satellite and AI for photovoltaic power station detection. For example, the analysis of large-scale high-resolution satellite image data, can identify the distribution map of China's more than 500 photovoltaic power plants, a total area of 2000 square kilometres (equal to that of ShenZhen), and complete correlation analysis for the country and enterprises. This provides

Alternative Data Source
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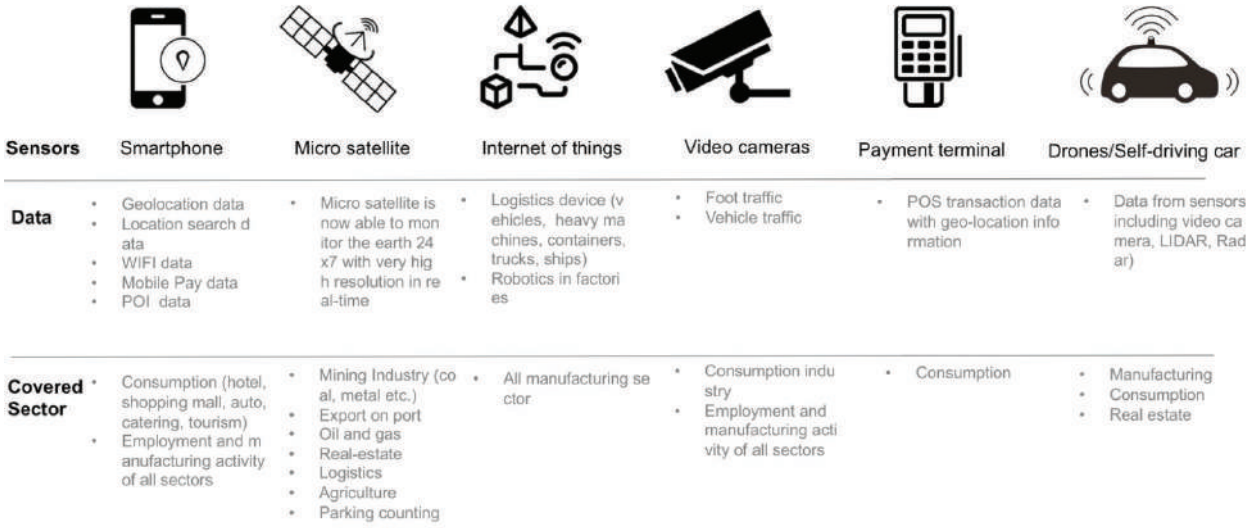
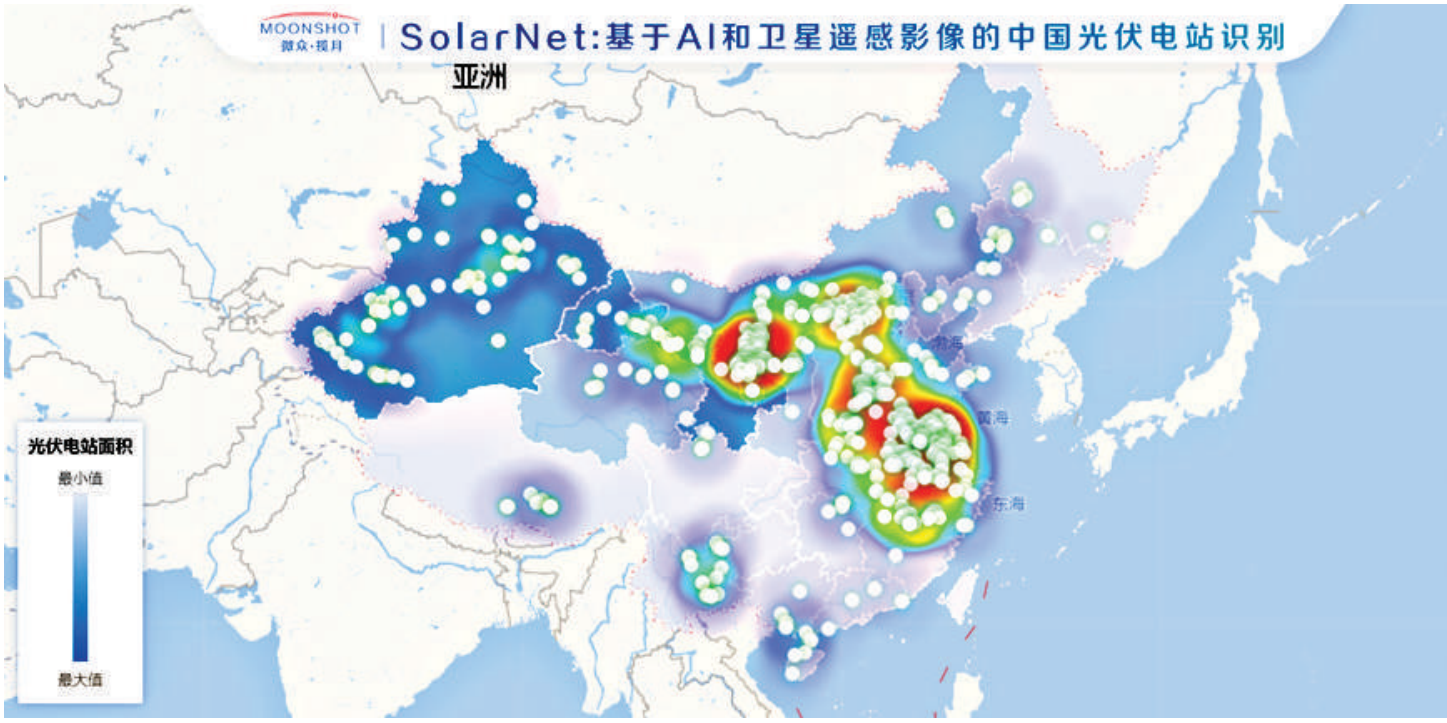


Sensors	Smartphone	Micro satellite	Internet of things	Video cameras	Payment terminal	Drones/Self-driving car
Data	• Geolocation data • Location search data • WIFI data • Mobile Pay data • POI data	• Micro satellite is now able to monitor the earth 24 x7 with very high resolution in real-time	• Logistics device (vehicles, heavy machines, containers, trucks, ships) • Robotics in factories	• Foot traffic • Vehicle traffic	• POS transaction data with geo-location information	• Data from sensors including video camera, LIDAR, Radar)
Covered Sector	• Consumption (hotel, shopping mall, auto, catering, tourism) • Employment and manufacturing activity of all sectors	• Mining Industry (coal, metal etc.) • Export on port • Oil and gas • Real-estate • Logistics • Agriculture • Parking counting	• All manufacturing sector	• Consumption industry • Employment and manufacturing activity of all sectors	• Consumption	• Manufacturing • Consumption • Real estate

decision-making reference in renewable energy development. This may be the first attempt to use deep learning framework to reveal the location and size of China's solar power plants.

China has become the world's largest investor in solar PV. Statistics from China's National Energy Administration show that by the end of September 2019, the country's total installed photovoltaic power capacity had reached 190,019 million kw, up 15 percent year on year. In the first three quarters of 2019, China's photovoltaic power generation reached 171.5 billion kilowatt-hours, up 28 percent year on year. The development of distributed photovoltaic and the innovative application of energy storage technology will bring huge ecological and environmental benefits, significantly reduce environmental pollution, and reduce greenhouse gas emissions from the Source of energy supply.

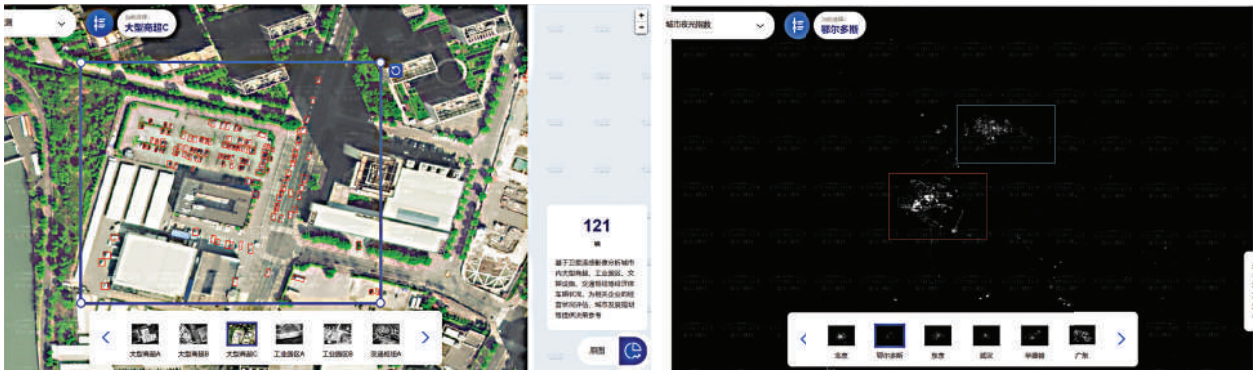


Distribution map of China's photovoltaic power stations based on AI and satellite remote sensing images
© **WeBank AI**

Therefore, detecting the distribution location and scale of photovoltaic power stations has threefold significances for sustainable investment:

- for the government, how to design and carry out better photovoltaic industrial policies, such as changing subsidy design and adopting quota subsidies, etc. to measure the relationship between photovoltaic energy and sustainable development;
- for enterprises in related industries, to measure and quantify the situation and efficiency of photovoltaic production;
- for investors, the location, trend, and opportunity prediction of future photovoltaic power stations.

The combination of Senseable Economics and sustainable investment goes far beyond that. Based on remote sensing images, unmanned aerial vehicles, spatio-temporal data, as well as the public opinion of "alternative" data such as data analysis, mining real-time, intelligent, and comprehensive information, real-time monitoring of macro-economic development trend, accurate diagnosis of urban development pulse, accurate quantitative business fundamentals closely track commodity trading, objective assessment of agricultural insurance losses, and the objective index of the ESG rating companies.



Vehicle index and luminous index in a certain area © **WeBank AI**

Road network density and regional variation in an area © **WeBank AI**

Application Scenarios 1: Evaluate the regional vitality index by identifying vehicles and luminous index combined with POI data

Vehicle flow detection:

Analyse the vehicle status of large commercial supermarkets, industrial parks, recreational facilities, transportation hubs, and other economies in the city and provide decision-making reference for the assessment of sustainable operation status of related enterprises and urban development planning;

Regional noctilucent image monitoring: construct regional economic index, then quantify macroeconomic development trend, and provide reference for regional policy formulation and regional investment strategy;

Road network density monitoring:

The road network density within the region can be used to measure various regional macroeconomic indicators, and the road network density index can be constructed to provide reference for infrastructure investment, urban planning, poverty alleviation evaluation, etc.

Application Scenarios 2: Evaluate and predict agricultural credit and insurance

Disaster Risk Map:

Based on multi-dimension remote satellite imagery, quantitively analyse meteorological disaster, disaster situation of agricultural diseases and insect pests, potential impacts of climate change, providing references for insurance underwriting and loss assessment;

Food Crops Area Prediction:

Based on multi-dimension remote satellite imagery, detect and monitor different kind of food Crops and Crops Area, providing references for food commodity futures investment strategy and grain yield.

Application Scenarios 3: Environmental Pollution Map

Mobile-based air quality monitor:

Combine mobile-phone photos with deep learning algorithms to collect characteristics for computing Air Quality Index (AQI), and mobile phones take the place of independent monitoring equipment. In China, current detection mostly relies on authorities' monitoring stations, but these stations turn out to be non-balanced distributed and group along coastal cities and first-tier cities. The coverage areas of these stations are 3 km and in the west part, there is lack of detection points.

Factory Environmental Monitoring:

Detect the flowrate, pollution, predict and analyse the situation of emission.

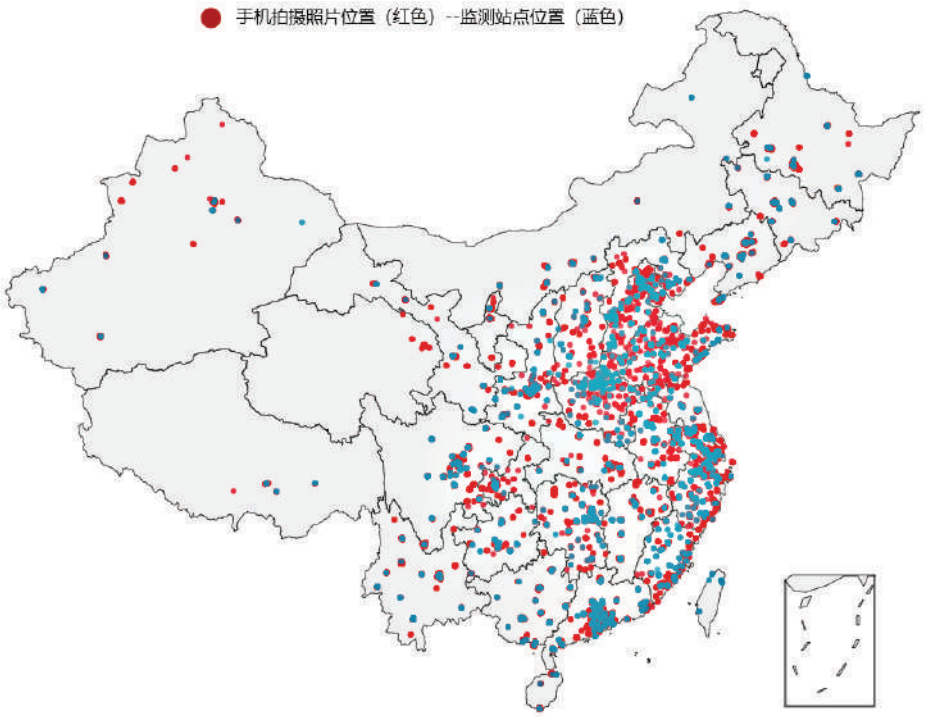
Application Scenarios 4: Green finance and financial risk monitoring

Integrate public opinion data with data owned by regulators, monitor the real-time situation of Green Finance and Financial risk, and complete relationship spectrum analysis.

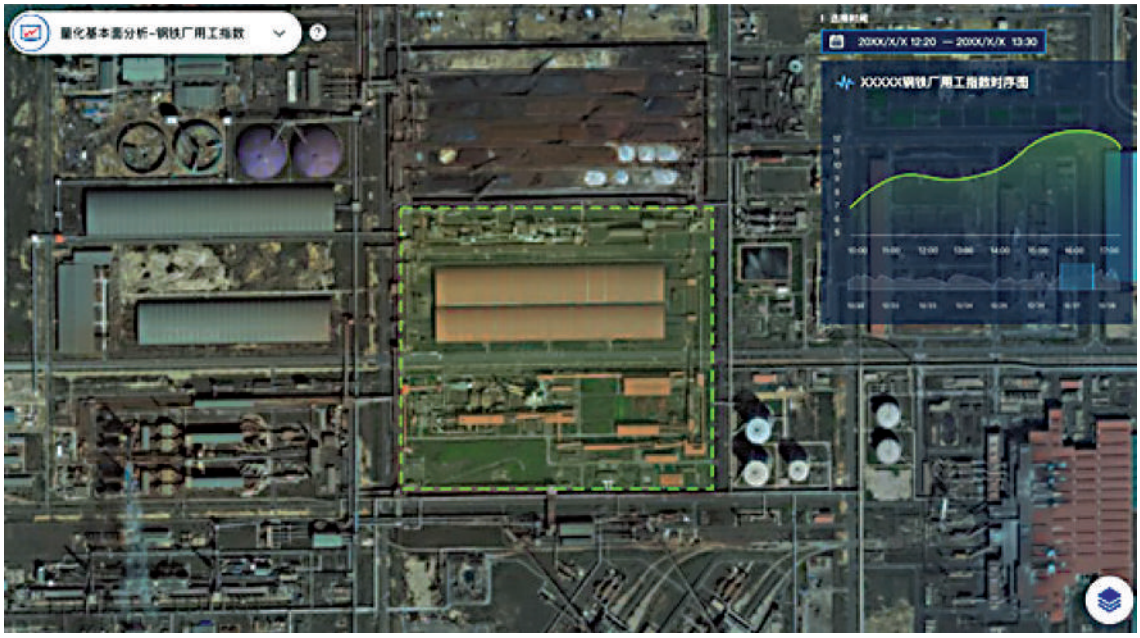
Remote satellite imagery would be monumental treasures. With the mature of aerospace technologies, the satellite

Business district activity index distribution map © **WeBank AI**

Crops Yield Prediction and Disaster Risk Prediction © **WeBank AI**



Distribution map of mobile-shot location and monitoring stations © **WeBank AI**



Workload Index of Factory © **WeBank AI**

become smaller and the cost decline, while the launching amount increase and the data transmission tech become more steady. This achieves hour-period updates for earth monitoring. In the forthcoming five years, Commercial Satellite accounts for 70 percent and application of remote satellite imagery enters the period of booming.

Within the application of remote satellite imagery, the transmission usually utilizes off-line method and the data is dealt with on the ground, causing three-hour hysteresis. To reduce the hysteresis effects and achieve real-time analysis, the most affective method is that the algorithm must be carried on the satellite and undertake data analysis in the space. But the overall power dissipation of a small satellite is under 100 W and it only offers 10 W support for a remote sensing algorithm chip. How does one operate AI algorithms under the low-power consumption requirements? That is why on-orbit computing makes great sense, it carries the AI algorithms on the satellite in orbit for real-time analysis.

Chapter Three of Application

AI-driven ESG: Data-driven ESG Investment

The ESG investment is just in time

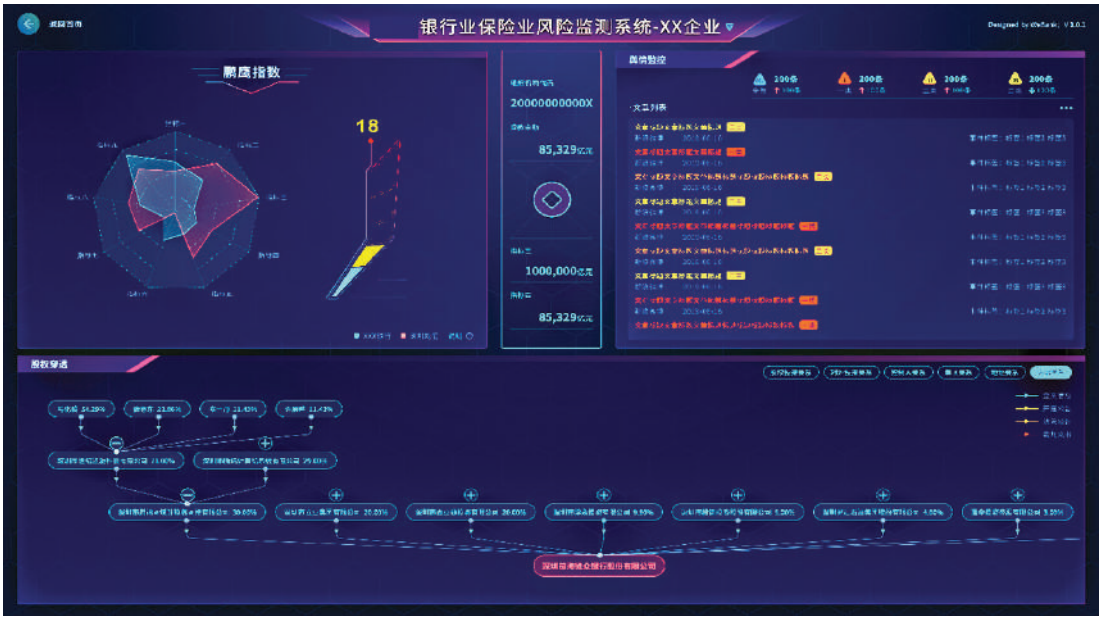
ESG investment consists of three parts: Environmental, Social, and Corporate Governance. Its core philosophy is to advocate full consideration of Environmental, Social, and corporate Governance factors in investment decision-making. On November 26, 2019, MSCI raised the inclusion of China's large-cap a-shares in the MSCI index from 15% to 20%, adding China's mid-cap A-shares to the MSCI index with 20% inclusion. Industry insider believe this will bring the largest ever flow of foreign capital into the domestic A-share market.

As Lawrence Fink, chairman and CEO of Blackrock, stated in his 2020 letter to corporate

CEOs, investment risk from climate change will accelerate the massive reallocations of global capital. First, to provide a sustainable, resilient, and transparent portfolio of products; Secondly, promote investment in sustainable development; The third is to strengthen the communication between the target enterprise and the full exercise of voting rights. In particular, Blackrock is gradually removing publicly traded equity and debt from its $1.8 trillion active portfolio of companies that produce more than 25% of their revenue from thermal coal, and plans to fully exit such holdings by mid-2020.

In recent years, products with ESG investment or similar responsibility investment gradually show the advantages of relatively strong anti-risk ability and relatively stable long-term return, hence becoming a mainstream investment concept and style in the capital market. There are 90 international exchanges that have joined the UN Sustainable Stock Exchange Initiative (SSEI), covering 16,000 listed companies and issuing ESG guidelines and requirements for these listed companies. By 2018, the scale of global ESG funds has exceeded US $1 trillion. ESG's investment in China's asset management market is

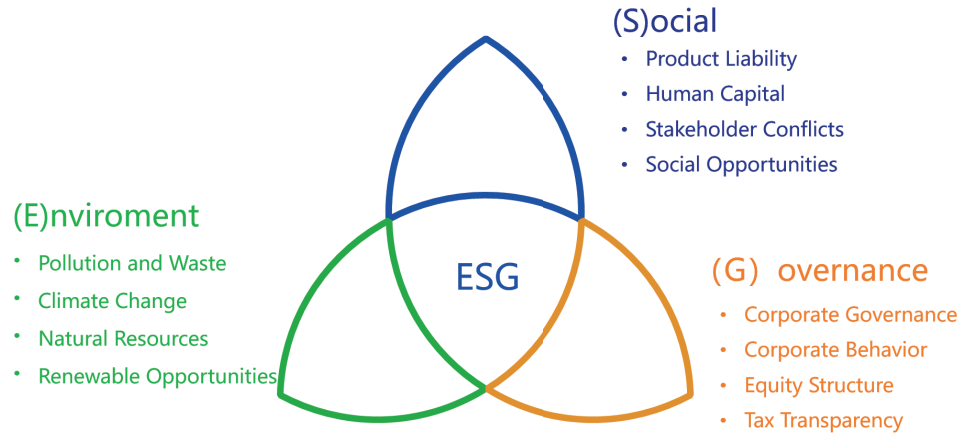
Banking and Insurance Industry Monitoring System © **WeBank AI**



Key Enterprises relationship spectrum analysis © **WeBank AI**

booming and has a huge space for growth. Several public offering funds have launched ESG theme funds, and the scale of ESG wealth management products from banks such as a China-based bank has already exceeded RMB 10 billion.

China's ESG rating system is on the rise. Since 2008, the scale of China's ESG index and green index has grown rapidly. By November 2019, Chinese financial institutions had launched 111 ESG-related funds, with assets of RMB 72.4 billion. In recent years, based on its own responsibilities and information disclosure regulation, the China Securities Regulatory Commission (CSRC) has urged and guided listed companies to strengthen ESG information disclosure, providing basic support for ESG investment and evaluation. On Jan 3rd 2020, the China Banking and Insurance Regulatory Commission (CBIRC) launched the guidance policy to promote banking and insurance industry, highlighted ESG management as the inclusive principles for high-quality development of banking industry, and urged ESG indicators to adopt in the whole process of operation including credit evaluation business.



ESG investment is expected to become a global trend in asset management.
ESG Evaluation system © **WeBank AI**

Regulatory policies of ESG in China © **WeBank AI**

Time	Regulator	Title	Summary
2002.01	CSRC	Listed company governance code	The disclosure scope of governance information of listed companies has been clearly stipulated
2007.04	SEPA	Measures for the disclosure of environmental information (trial)	Enterprises are encouraged to voluntarily disclose relevant environmental information through the media, the Internet or their annual environmental reports
2007.12	SASAC	Guidance on the fulfillment of social responsibility by central enterprises	The establishment of a social responsibility reporting system will be incorporated into the main content of the fulfillment of social responsibility by central enterprises
2008.02	SEPA	Guidance on strengthening the supervision and management of environmental protection of listed companies	SEPA and CSRC shall establish and improve the coordination and information reporting mechanism for environmental supervision of listed companies, so as to promote the true, accurate, complete and timely disclosure of relevant environmental information by listed companies, especially those in heavily polluting industries
2010.09	MEP	Guidelines for environmental information disclosure of listed companies	To standardize the time and scope of disclosure of information in annual and interim environmental reports of listed companies
2017.12	CSRC	G.n. 17 and g.n. 18	To encourage departments to disclose the work of actively fulfilling social responsibilities according to the characteristics of the industry
2018.09	CSRC	Revision of the governance standards for listed companies	The chapter on stakeholders, environmental protection and social responsibility was added, which stipulated that listed companies should disclose environmental information (E), poverty alleviation and other social responsibilities (S) and corporate governance related information (G) in accordance with laws and regulations and requirements of relevant departments.
2019.11	AMAC	ESG evaluation system of Chinese listed companies ESG information disclosure quality evaluation report of Chinese listed companies	Based on the practice of China's capital market, a basic and meaningful ESG value coordinate and behavior benchmark should be established to promote asset management institutions to adhere to the long-term perspective and integrate ESG into the investment decision-making process

Data-driven ESG investment strategy

Currently, ESG investment mainly focuses on negative elimination, ESG integration, active shareholder strategy, and other standard screening strategies. Among them, ESG factor Integration is a relatively systematic and explicit integration of incorporating ESG factors into the process of investment analysis for decision-making. Specific implementation methods of ESG can be customized according to the objectives of investors. ESG investing can be done in a numerous of ways, including adding ESG scoring to the traditional investment process, primarily to identify ESG-related risks. Another approach is thematic investments that focus on capturing specific opportunities in specific areas such as low-carbon energy or electric vehicles. It can also be invested through impact investment, which, in addition to earning a return, is expected to achieve tangible non-financial results such as energy and water conservation. Specific portfolio mandates such as green bonds are good examples.

Enterprises will voluntarily disclose social value data through CSR and ESG reports. Unlike traditional financial reporting, which has mandatory regulatory disclosure requirements, CSR/ESG reporting now takes the form of voluntary disclosure. Financial statements are disclosed in accordance with the general accounting standards, while for CSR/ESG reports, although some international organizations are promoting the standardization of disclosure, the disclosure

ESG investment strategy classification © **WeBank AI**

Target	Data Support	Risk Appetite	No.	Strategy Description	Comment
Elimination of High ESG Risk	Rating	Aggressive	1A	Low ratings are removed from the benchmark and the rest are weighted according to market capitalization	Avoiding unwanted ESG risk, but tracking errors to the benchmark become larger
		Stable	1B	Remove low ratings from the benchmark and optimize the weight of the remaining components to minimize tracking error	The tracking error of the benchmark is small, but the component stocks with high correlation of the underlying risk will be highly matched and eliminated
Theme Investment	Scoring	Aggressive	2A	The restricted tracking error is the same as 1B, and all component weights are optimized to maximize the corresponding ESG index score of the theme	Large tracking error to reference
		Stable	2B	The defined topic corresponds to the same ESG index score and 1B, and all component weights are optimized to minimize tracking error	Through correlation, more risk exposures are generated that deviate from the theme
Elimination + Theme	Rating + Scoring	Aggressive	3A	The expected topic is defined to correspond to the ESG index score, and the weight of 1A is optimized to minimize the tracking error of 1A	Large tracking error to reference
		Stable	3B	The expected topic is defined to correspond to the ESG index score, and 1A weight is optimized to minimize the tracking error to the benchmark	Through correlation, more risk exposures are generated that deviate from the theme

requirements among organizations are not relatively consistent. In addition, financial statements are audited by audit firms, and CSR/ESG reports have no audit requirements, leaving room for greenwashing by individual companies.

The existing ESG data have the following defects:

- **Quality:** most of the data are voluntarily disclosed by enterprises, resulting in the defects of reliability and consistency. The key is to improve corporate disclosure standards and establish a sound disclosure framework.
- **Consistency:** different data providers assign different weights to ESG indicators, which means that the scores of different suppliers are of low correlation and may have significant differences with each other, which cannot be compared with credit ratings.
- **Coverage:** most ESG data cover only about 10 years, and many asset classes cover even less. Compared with small enterprises, large enterprises tend to report more complete ESG indicators, so they are important in the index. Areas such as emerging markets and high-yield bonds have even less coverage.
- **Frequency:** many ESG indicators are only updated once a year, so it is difficult to form the most time-sensitive view of managing risk or improving return through the analysis of these indicators.

AI+ alternative data-driven
ESG indices and ratings
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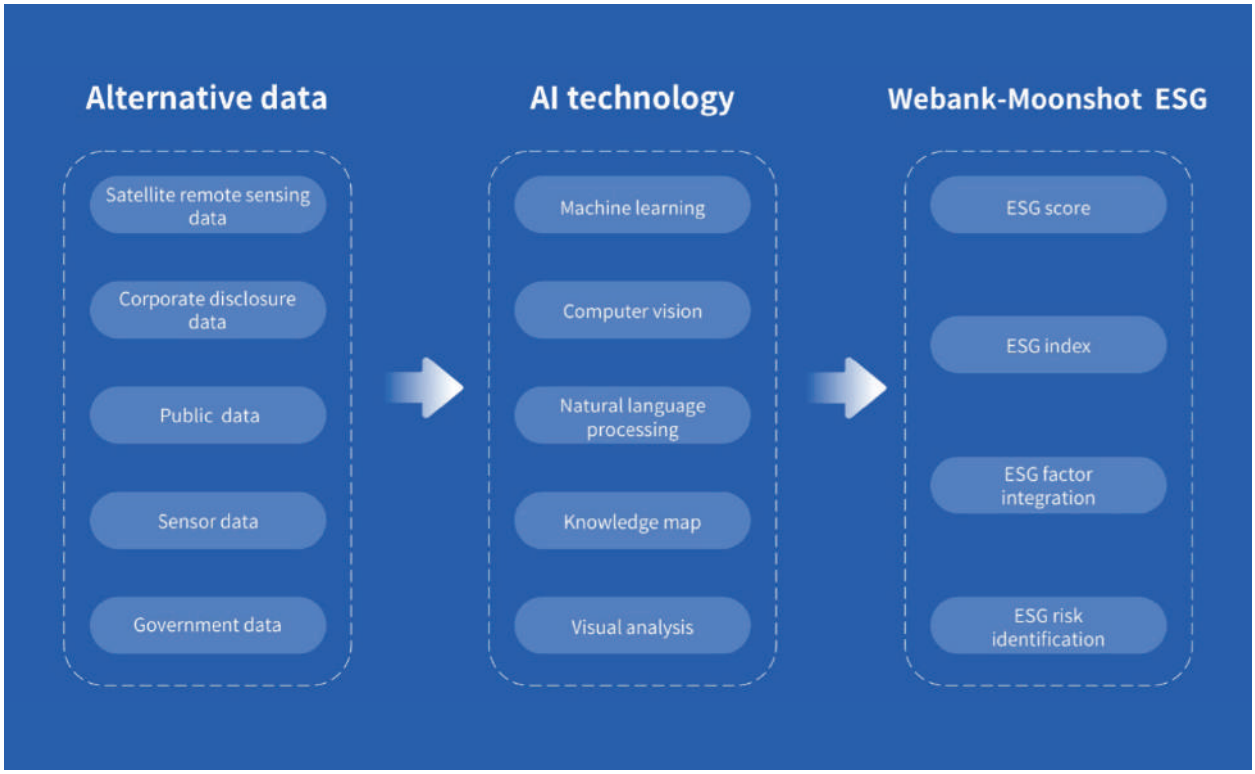

ESG investment lacks of data support globally. This challenge is also a great opportunity for data as it is where AI technology and alternative data come into play.

First, for example, the monitoring of environment-related indicators in "E" by satellite remote sensing images. Computer Vision (CV) technology in AI combined with hyperspectral satellites, radar satellites and other satellite images can be used to analyze the environmental performance of manufacturing production units, such as exhaust emissions, waste water emissions, cofferdam and other conditions.

These analyses can be used to examine corporate reporting data and identify greenwashing. At the same time, CV combined with the street view pictures of social media can be used to analyze the local air quality, so that local residents can participate in the environmental monitoring of enterprises, which is both the audience of enterprises' environmental performance and an effective supervisor.

TOPICS	ILLUSTRATIVE METRICS	FREQUENCY
Resource Efficiency	GHG emissions	92%
	Water use	92%
	Energy efficiency and mix	85%
Pollution Prevention	Waste (water, solid, hazardous)	73%
	Air pollutants	62%
	Pollution risks	42%
	Spills	25%
Biodiversity Conservation	Protection of habitat and biodiversity management	46%
	Impact on endangered, vulnerable, or rare species	23%
Climate Adaptation	Prevent or adapt to climate change	38%

E (environment) indicator in ESG © **IFC, WeBank**

Then, for example, public sentiment and graph analysis are used to monitor relevant indicators such as supply chain and corporate governance structure in "S" and "G". The financial performance of enterprises will affect the equity of shareholders, while the ESG performance of enterprises will affect the broader group. Supervision by regulatory authorities, social media reports, and public sentiment evaluation are objective reflections of the ESG performance of enterprises. Natural Language Processing (NLP) technology in AI can automatically identify the enterprise, classify the types and severity of regulatory penalties, analyze the events mentioned in public sentiment and the controversy impact, and also perform the process map analysis to track the evolution of events. ESG analysts can use the power of AI in "fishing for a needle in the ocean" without missing key risk information.

ESG risks are transmitted through corporate relationships, most commonly through equity and supply chain. Environmental problems in water enterprises, for example, will affect the production activities of the beverage industry. Knowledge Graph (KG) in AI can establish a large Graph database of various association relationships and enterprise attributes, then identify the undisclosed connections between enterprises according to the Graph mining algorithm, and analyze the path and degree of ESG transmission. ESG analysts can have a global perspective to identify and analyze risks as well as make timely countermeasures to avoid risk contagion.

In Addition, AI can be used to populate undisclosed enterprise defaults for the quantifiable value of the ESG metric. The traditional method of filling will use the data of the same industry disclosure enterprises,

Graph analysis of public opinion and equity/supply chain/industrial chain
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take advantage of the similarity of the same industry enterprises, and fill the default values. Contemporary enterprises have a wide range of business lines, and simple industry classification cannot describe the similarity well. AI clustering algorithm can achieve more accurate similarity analysis, so that the default value filling is based on the most similar enterprise characteristics and so that the filling value will be closer to the real value.

Finally, the biggest advantages of data-driven ESG investment is real-time performance and data traceability, which could undertake correlation analysis to integrate effective factors with performance. The rating could adjust according to dynamic information such as real-time public opinion data and help investment institutes to detect ESG risk ahead of the announcement of financial reports. Therefore, the ESG rating could be divided into three perspectives:

- **Pulse Scores:** Reflect the ESG dynamic information of enterprises, detect real-time ESG risk. Higher scores represent lower ESG risk.

- **Insight Scores:** Reflect the overall long-term an short-term ESG risk. Higher scores represent better ESG performance.

- **Motion-energy Scores**: Reflects the changing trend of enterprises' risk. Higher scores represent the improvement of ESG performance within one year.

Technology links sustainable future!

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UNITED NATIONS HUMAN SETTLEMENTS PROGRAMME
P.O. Box 30030, Nairobi 00100, Kenya
T: +254-20-76263120
E: infohabitat@unhabitat.org

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