THE ARCHITECT AND ARTIFICAL INTELLIGENCE
A NEW DILEMMA

by YU YIN CHAN

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AND
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Student
Yu Yin Chan   10523939
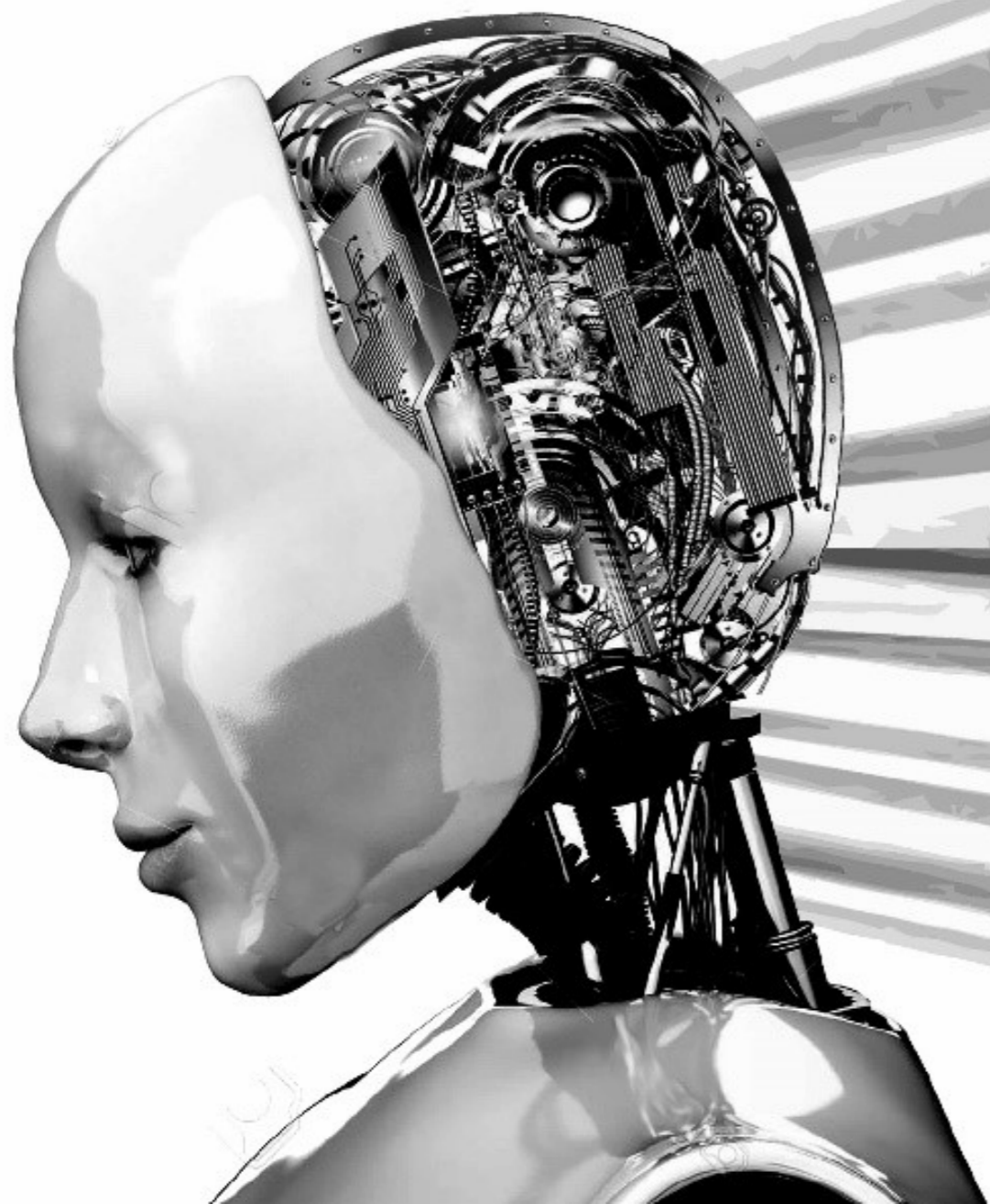
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ARTIFICIAL INTELLIGENCE
machine learning

ABSTRACT

Key words

Artificial Intelligence (AI), Architecture , City Brain, Hangzhou City Brain, China , Chinese Smart City , Urban Design

Technology has long been part of our lives, to help us sometimes and of course to harm us sometimes. It still surprises us although it has seamlessly blended into our lives. Artificial Intelligence (AI) is one of the advancements in technology which has already been penetrating the world, especially in China, it also penetrates the architectural and urban design world.

A New York-based designer, Sebastian Errazuriz, posted a controversial claim in a series of movies online: Ninety per cent of architects will lose their jobs as artificial intelligence takes over the design process. Will ninety per cent of architects really become jobless because of AI? What is AI? Why did he make such a bold statement? Did he play to the gallery or did he mean it by heart? No matter what his motives are behind, I am intrigued.

Architect is one of the oldest professions on earth, its importance has been accredited by time, innumerable renowned architects left their master-pieces as well as their legacies behind, professionals in conservations are willing to work hard and help them to pass their stories generations after generations, thanks to them, the Renaissance work or earlier can still be appreciated.

Looking at China, the development of AI is accelerating and it is expected to be exponential. With a focus on the Chinese context, will the architectural and urban design practice absolutely be disrupted by AI so architects become obsolescent? Will it be a substitution of architects with AI? If not, what will the future architects be?

To answer these core questions of this paper, firstly, a clear explanation of smart city and AI is a prerequisite to comprehend how and why AI suddenly took place in China which are elaborated in chapter two, three and four. Then, based on those concepts, in the following two chapters, five and six, to understand why AI came out from the academic world and took a city by storm, how AI has been applied and affects people's lives learning from real-life examples found in China. From those case studies, they reveal the changes made by AI, among all the changes, what are the aspects that would affect the life of being an architect in China? In chapter seven, it would take a deeper look, to see would those changes be significant enough to take over architects so they eventually become superannuated? Or AI is simply an advanced tool for people to architect their intelligence? To conclude the entire paper, in the closing chapter, a reflection is made to remind myself or hopefully to inspire the others how to cope with the changes in this profession, to those aiming at practicing in China.

AI & Deep Learning

https://www.facebook.com/101997311542367/
posts/why-our-brain-is-the-most-intelligent-
machine-of-allthe-idea-of-intelligent-ma-
ch/147611700314261/

AI Superpowers
China, Silicon Valley
and the new world order

Anti-Capitalist Chronicles

Smart City Indicators

Assessing smart city projects
and their implications for
public policy in the Global South

P.R.C. Government documents

Other resources

Economical Framework in China

Smart City Discourses

A.I. Discourses

Case Studies in China

IS AI A TOOL OR A THREAT?

REFLECTIONS

CHAPTER 1|

INTRODUCTION

The digital way of living no longer only belongs to science fiction books or movies but us. This "novelty" has been pushed forward by the pandemic all over the world despite in some contexts maybe more apparent than the others. In China, lives have been transformed and still transforming, even before the outbreak, the strategic economic reform in China in the last decade has already seen its impacts reflected in multiple dimensions, not only in terms of numbers but in far-reaching applications covering countless aspects in everyday life. Supporting and embracing the digital era coming from deep-seated yearning for changes and improvements, its implications have reached the lives of many Chinese citizens, Artificial Intelligence (AI) is one of the technologies being accelerated during the digital reform and influences us swiftly and profoundly.

1.1 From Agricultural To AI

Kai Fu Lee, AI expert, venture capitalist investor, writer and speaker, travels around frequently to deliver speeches on AI. He does not only share his expertise with like-minded people and intellectuals but he also accepts invitations from kindergartens. Recalling his talks given to the kindergarteners with the same topic given to the members of global business and political elicits,to his surprise, he notices that these two distinctively different audiences often ask similar questions which echo to each other: would we have robot teachers? Would people get married with robots and have babies with them? Will computers become too smart and boss us around? If robots do everything then what will we do?

As a would-be architect and urban designer, I also ask myself will AI take over me? Its influences trigger the concerns of the labour market, especially worries over employment: AI is so powerful that it revolutionises the labour market, eventually taking over employment which is currently occupied by human beings. The technology of autonomous driving has become mature enough to be a threat to professional drivers' livelihood*. Would architects be the next to be threatened?

With a focus on the Chinese context, will the architectural and urban design practice absolutely be disrupted by AI so architects become obsolescent? Will it be a substitution of architects with AI? If not, what will the future architects

* https://www.forbes.com/sites/patrickwwatson/2017/08/31/technology-is-already-eliminating-driver-jobs-heres-how-to-trade-it/?-sh=718e9ba3b6d4

AI & Deep Learning

https://www.facebook.com/101997311542367/posts/why-our-brain-is-the-most-intelligent-machine-of-allthe-idea-of-intelligent-march/147611700314261/
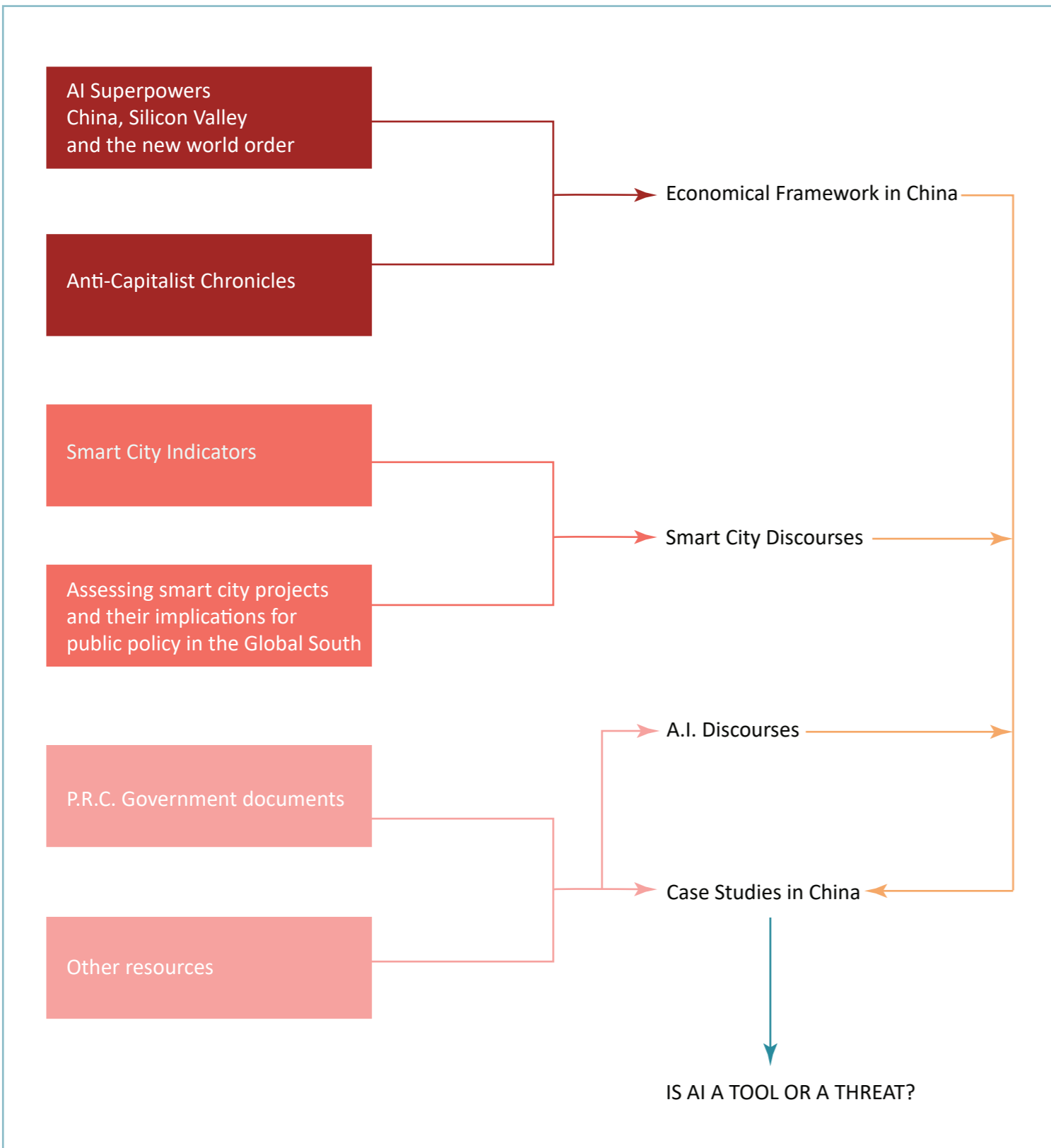
be? These are the main research questions for the paper and the starting point of presenting the discourses organised into several chapters:

The first part includes three chapters which introduce the basic framework of the work, beginning with the economical background of China, passing to the definition of smart city and then AI. Chapter two rolls out the economic setting in China, to explain concisely how its economic reform has led the country going towards the digital development and era from an economy originally rooted in agriculture and later relied heavily on export. Chapter three defines what a smart city is, describes how it looks and why becoming smart, giving an overall view of its development around the globe before having a more specific view on China. Chapter four defines AI and briefly explains its development. It is necessary to have a basic understanding of AI thus to grasp the significance of AI in the following chapters concerning the case studies and its applications together with its impacts.

The following part includes chapter five and six, about the case studies found in China. The first case study is an ongoing project in Hangzhou called City Brain Hangzhou. AI is incorporated seamlessly into the project and the success of this allows the concept to expand and apply in other Chinese cities and even in a non-Chinese city, Kuala Lumpur. Hangzhou is already a relatively well-developed city in China prior to the implementation of the City Brain project, yet the adoption of AI is not restricted to its existing fabric or structure of the city which shows its flexibility in operation. The second case study is an ambitious project, a project to build a future city. Xiongan New District was assigned to participate in the millennial plan of realizing this ambition from scratch. Unlike the first case study, the applications of AI in Xiongan New District are incorporated at the beginning of its construction which give even a more comprehensive perspective of its impacts on the architectural related professions. The main purposes of this part are to demonstrate the real applications of AI in the real world which facilitate the discussion in the final part.

The closing part includes chapter seven and eight, based on the previously discussed case studies, the core objective of it is to find out the changes and impacts made and left by AI in connection with architecture or urban design before answering to the research questions posed at the beginning. Chapter seven focuses on both the supplementary and substitutive role that AI is capable of playing, learnt from the case studies and other extra examples which might be seen in China in the future. These findings are crucial to formulate the final chapter, chapter eight is answers to the research questions at the same time a reflection to remind myself how to embark my architectural journey in this digital era.

1.2 Methodology

The methodological approach of this paper adopts the qualitative method, in order to comprehend the concepts, qualitative research has been applied involving analysis of extensive sources of material produced by different scholars, experts and professionals, books, research papers, reports, interviews, news, press releases, online lectures, online presentations ...not restricted myself to architecture and urban design only but looking at the research topic at a wider perspective and zooming closer at the end as I believe architecture and urban design can never be seen as a topic completely isolated and separated from other professions. The major sources are summarised as the followings:

A book written by, Kai Fu Lee, AI Superpowers: China, Silicon Valley, and the New World Order sets up the foundation of the paper, his exceptional knowledge and experiences in AI and AI industry with an eye on the Chinese market open the conversation by how AI is entering China and suddenly taking the market by storm and spreading his so-called AI fever. His personal experience and ideas on the labour market inspire me to reflect the role of being an architect now and in the future.

David Harvey's online series Anti-Capitalist Chronicles fill the holes left by Lee, his deep understanding on Chinese economic history and background and his ideas projecting the upcoming future in the labour market in China help forming a more concrete base for the overall discourse. He stresses the complexity of urbanisation for many years, in particular its relationship between capital so it cannot be seen as a stand-alone phenomenon but an element of a complex system. Logic alike is applied by describing the context before commencing the elaboration on the architectural and urbanistic aspects, thus acquiring a better understanding of the latter during the discussion.

Rudolf Giffinger's idea on smart city indicators sharpen the focus of AI adopted in the smart city examples employed to discuss in the paper. Six different aspects are formulated in his theory, by looking at each aspect one by one, the combination of academic theory and real examples helps the readers to comprehend the roles of AI inside a city systematically and how it affects peoples' lives. To further assess the examples, the four types of typologies proposed by Prathivadi B. Anand in his research paper, assessing smart city projects and their implications for public policy in the Global South, are taken into considerations for gauging their extend and degree of incorporating AI into the cases, trying to sort out if it is a true AI project or an AI-wash project to capture the attention of the mass having AI fever.
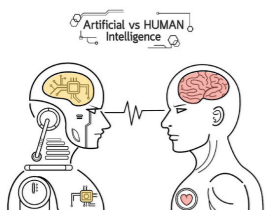
RESEARCH QUESTIONS

WILL AI TAKE OVER ME?

With a focus on the Chinese context, will the architectural and urban design practice absolutely be disrupted by AI so architects become obsolescent?

Will it be a substitution of architects with AI?

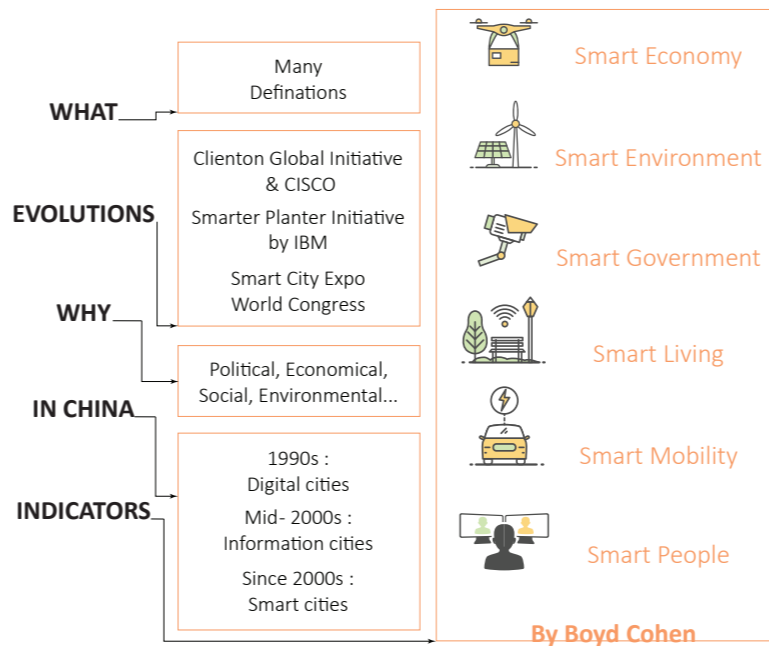If not, what will the future architects be?

ECONOMICAL BACKGROUND IN CHINA

Technology- based Urbanisation	2021	
Technology- based Urbanisation	2017	1st National Plan on AI
	2016	DeepMind Challenge Match
Energy- based Urbanisation	2008	Global Economic Crisis
	2007	Subprime Mortgage Crisis

Urbanisation has never stoped ever since but the fuel has changed through time

| Energy- based Urbanisation | 1978 | Open Door Policy |

THE BIRTH & RAISE OF SMART CITY

WHAT → Many Definations

EVOLUTIONS →
- Clienton Global Initiative & CISCO
- Smarter Planter Initiative by IBM
- Smart City Expo World Congress

WHY →

IN CHINA → Political, Economical, Social, Environmental...

INDICATORS →
- 1990s : Digital cities
- Mid- 2000s : Information cities
- Since 2000s : Smart cities

- Smart Economy
- Smart Environment
- Smart Government
- Smart Living
- Smart Mobility
- Smart People

By Boyd Cohen

THE BIRTH & RAISE OF AI

In **1956**, the term **Artificial Intelligence** first coined by Stanford researcher

Dartmouth conference   **John McCarthy**

25 years after the Dartmouth conference

Discuss what would become the field of AI, clarify and develop the concepts around "thinking machines"

ARCHITECTURAL DESIGN
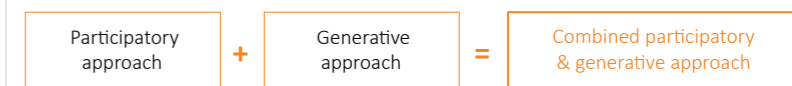
Parametricism → Statistical Approach ← Generative Adversarial Network

URBAN DESIGN

Participatory approach + Generative approach = Combined participatory & generative approach

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CASE STUDY - A CITY OF NOW AND FUTURE

Local talents | International talents

Plan, Design & Experiment

Construction

Sustainability | High - technology

Applications

AI has done ...
- ✓ Review design proposals
- ✓ Formulate urban strategies
- ✓ Manage construction
- ✓ Supervise construction
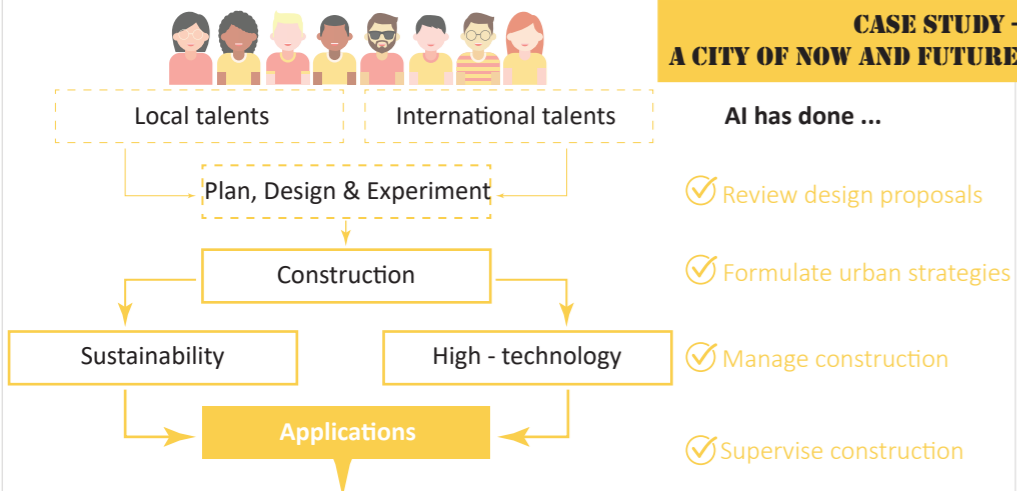
- Stimulate high-technology development : e.g. cross-border E-commerce Comprehensive Pilot Zone
- Intelligentise utility service : e.g. the digital active power distribution network
- Provide unmanned government service : e.g. first unmanned police station
- Digitalise amenities : e.g. unmanned supermarket, smart hotel, digital payment and RMB
- Build a digital and seamless transportation infrastructure network : e.g. smart highways, smart ports and smart waterways
- Incubate high-tech talents and enhance social inclusion : e.g. AI education laboratory, Smart and Safe Countryside monitoring platform

Explores new development models

Xiongan New Area

Develops future-oriented high-tech industries

Substitution
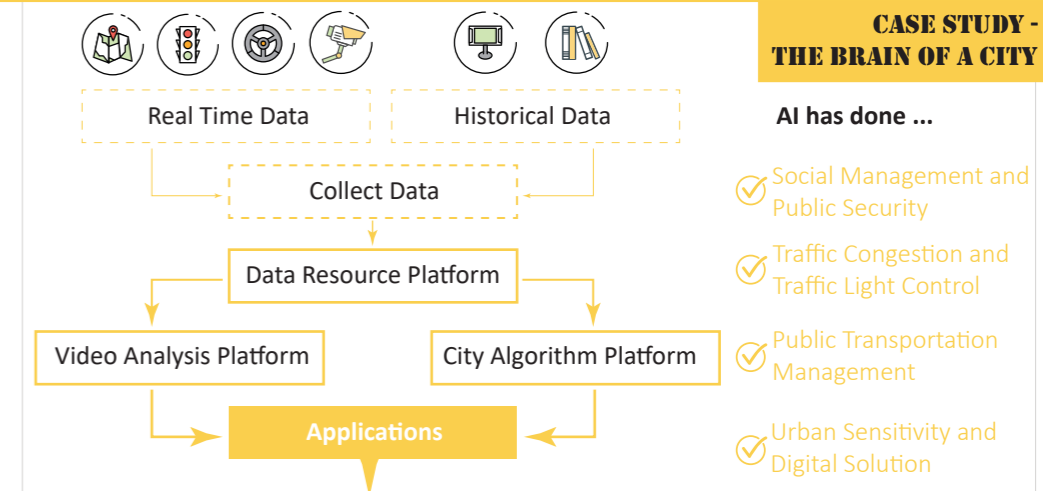- Research : Perform analytical tasks
- Design : Generate design options
- Construction : Take over dangerous tasks
- Management : Provide data and analysis at real time

Complementary
- Research : Underline the human presence
- Design : Propose solutions
- Construction : Offer simulations and alerts
- Management : Improve coordination

Substitution   **COMPLEMENTARY**

AI

IS AI A TOOL OR A THREAT ?

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CASE STUDY - THE BRAIN OF A CITY

Real Time Data | Historical Data

Collect Data

Data Resource Platform

Video Analysis Platform | City Algorithm Platform

Applications

AI has done ...
- ✓ Social Management and Public Security
- ✓ Traffic Congestion and Traffic Light Control
- ✓ Public Transportation Management
- ✓ Urban Sensitivity and Digital Solution

- Foster other smart development : e.g. agricultural industry- cattle / bees
- Allocate resources more effectively : e.g. take up only 10% of existing resource usage
- Better collaboration : e.g. a combined digital platform for all the government bodies
- More convenient : e.g. 37 scenarios with its applications, tourism, medical services
- Lessen traffic problems : e.g. a network of traffic lights to automate traffic control and management
- Enhance social inclusion : e.g. automatic alert to get help for the elderly when they have utility issues

Export the brain → Digital Twin-Cities

CITY BRAIN

A BRIEF ECONOMICAL BACKGROUND IN CHINA

* https://www.scmp.com/yp/discover/news/asia/article/3123702/china-claims-it-has-beaten-extreme-poverty-what-has-it

In 2021, during the Chinese New Year, a ceremony was set up by the Chinese Communist Party for announcing its "major victory" that would "go down in history"*. The victory refers to the success at eradicating extreme poverty which is an unprecedented goal set by the Party to achieve it by the end of 2020. Although this announcement set off international debates, according to The World Bank more than 800 million people have been lifted out of poverty since Chinese economic reform and its open-door policy in 1978**. It seems like a miracle after four decades, yet, believed that it was and still is a battle.

** https://www.worldbank.org/en/country/china/overview

2.1 Energy - Based Urbanisation

* https://en.wikipedia.org/wiki/Urbanization_in_China#cite_note-urbanizationrate-1

Urbanisation has been identified by the Party as part of this battlefield, in 1978 China, its total population lived in urban areas accounts for 17.92%* and the latest figure issued by The World Bank shows more than half of its population, reaching 60.308%** live in urban areas in 2019. Back to 2014***, it was already published that China used more concrete in three years (between 2011 and 2013) than the U.S. used in the entire 20th century which 6.6 gigatons of concrete were utilized. Urbanisation in China is not expected to come to an end but to continue, the magnitude might slow down, still, experts expect it to reach 65%^ or even 70%^^ by 2030.

** https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=CN&view=map

*** https://www.forbes.com/sites/niallmccarthy/2014/12/05/china-used-more-concrete-in-3-years-than-the-u-s-used-in-the-entire-20th-century-infographic/?sh=450cc6d64131

^ https://www.oecd-ilibrary.org/docserver/5k49dv68n7jf-en.pdf?expires=1618635585&id=id&accname=guest&checksum=5C8E46B3456C25A121EBA0E312176513

^^ http://www.chinadaily.com.cn/a/201906/24/WS5d1089b0a-3103dbf14329ea7.html

Chairman Mao in Discussion with the Peasants of Shaoshan

This work is a revision of Yu Youhan's 1991 painting of the same title which was based on an official photograph of Mao visiting peasants in his home town of Shaoshan, Hunan Province.
Source: M+ Sigg Collection, H. K.
By donation, © Yu Youhan
https://collections.mplus.org.hk/en/objects/chairman-mao-in-discussion-with-the-peasants-of-shaoshan-20121309
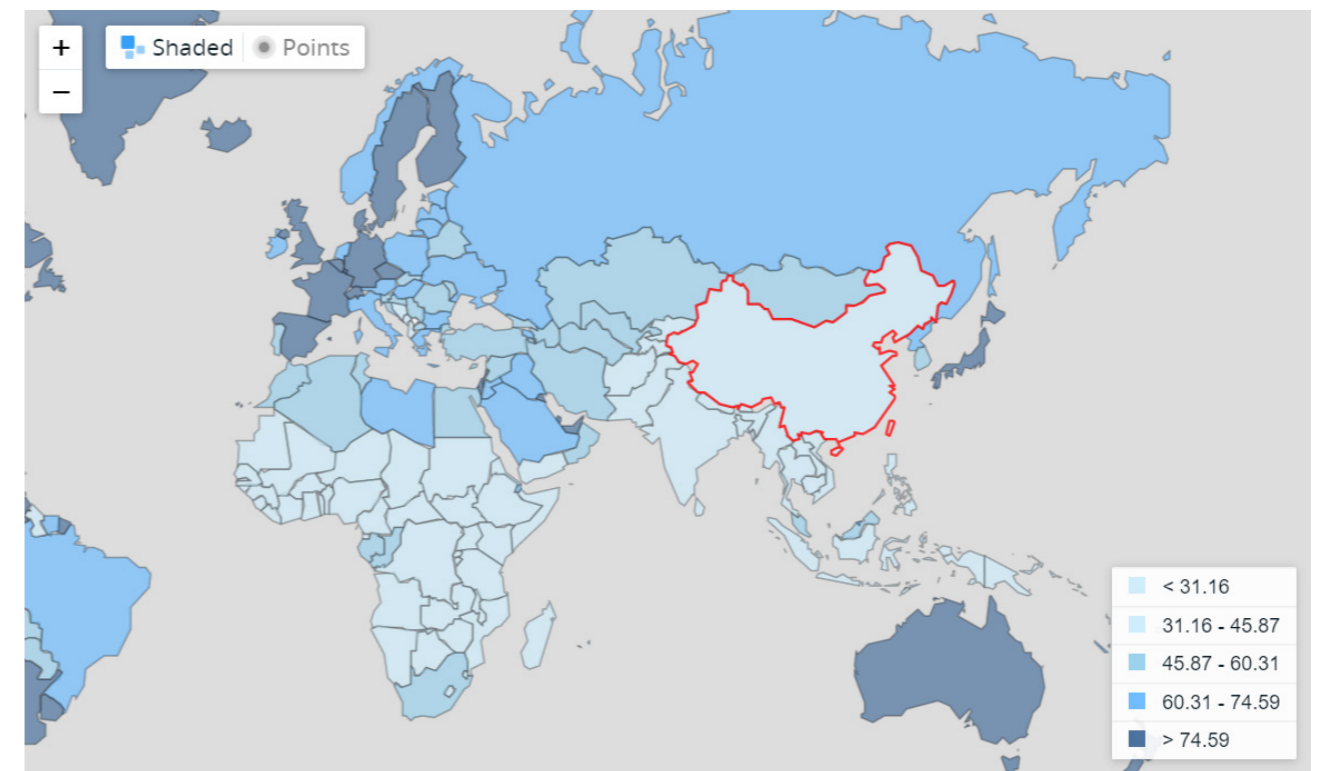
Living in the same global village, China is also facing severe environmental problems, like many other nations on earth. Urbanisation is a powerful engine for its rapid development but at the same time lots of energy is needed to fuel this engine. Taking all the supply chain into consideration, constructing a city and living in a city require almost unimaginable amounts of energy and resources. Back to the time where the concept of sustainability was still well-kept among the academic elites in China. An energy-based urbanisation model adopted in China for decades has proven its inadequacy, such inadequacy is manifested in many aspects, the environment is undoubtedly one of them. The severity of air pollution has already been alarming, the capital city Beijing houses approximately 20 million people, has suffered from and blanketed in choking smog. (Fig2.1.4). There are more examples which can be quoted.

Around 2007 and 2008, China received a wake-up call. Led by the bankruptcy of major financial institutions in the US, the global economy was crushed, nations were entered into a global financial crisis. The consumer market in the US had nearly collapsed, the World's factory, relied heavily on exports, especially to the US, could not escape from this crisis and suffered. This was the moment when China was punched but this was also the moment when it realised a transformation is a must. Moreover, the consequences of the One Child policy started to reveal, with the changing in the demographic structure, the Party understood that labour surplus does not last forever, in other words (Fig.2.1.1), its labour-intensive forms of production cannot be its comparative advantage or economic direction forever. Knew that changes are a must, they were planning and searching for them. Nevertheless, during the years of searching and testing, urbanisation was not only retained but growing and generous spending on physical infrastructure, such as high-speed trains, kept the workers busy to absorb the labour surplus resulting from the global economic turmoil (Fig.2.1.7). Choosing an opposite strategy different from the other affected nations, the non-stop urbanisation keeps the Chinese economy moving between the transitional period. (Democracy At Work, 2019)
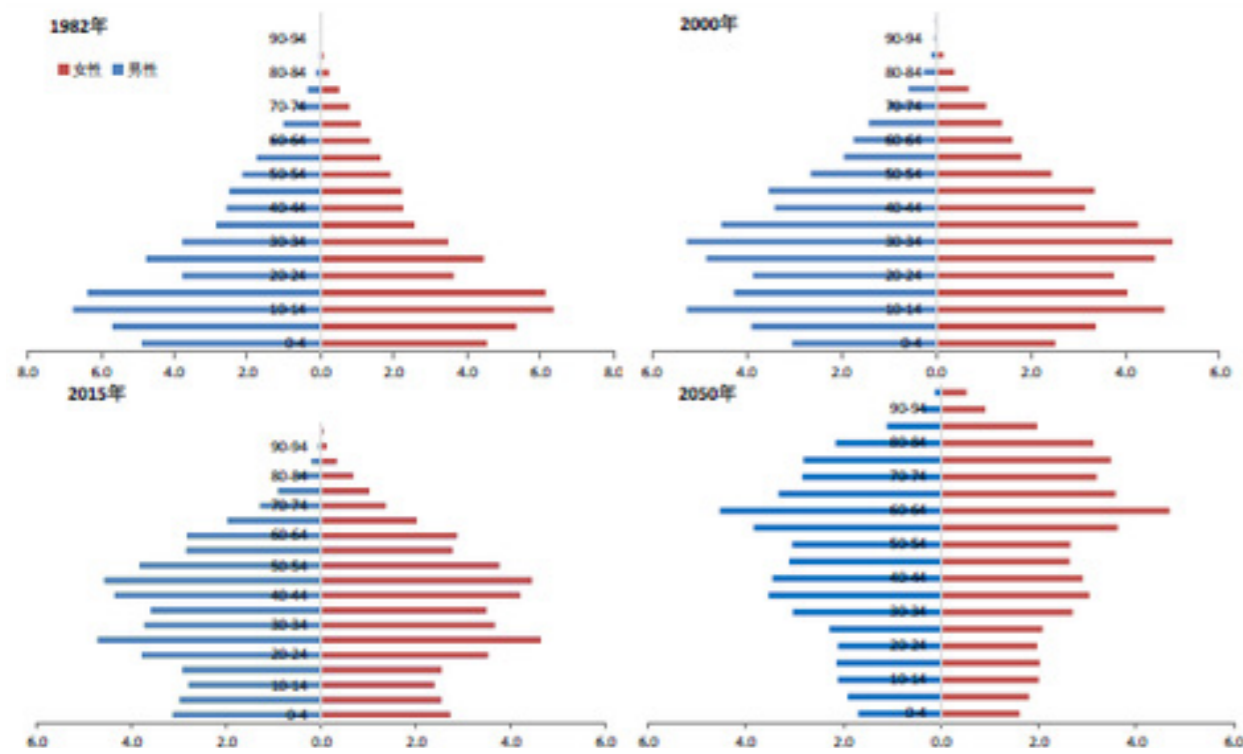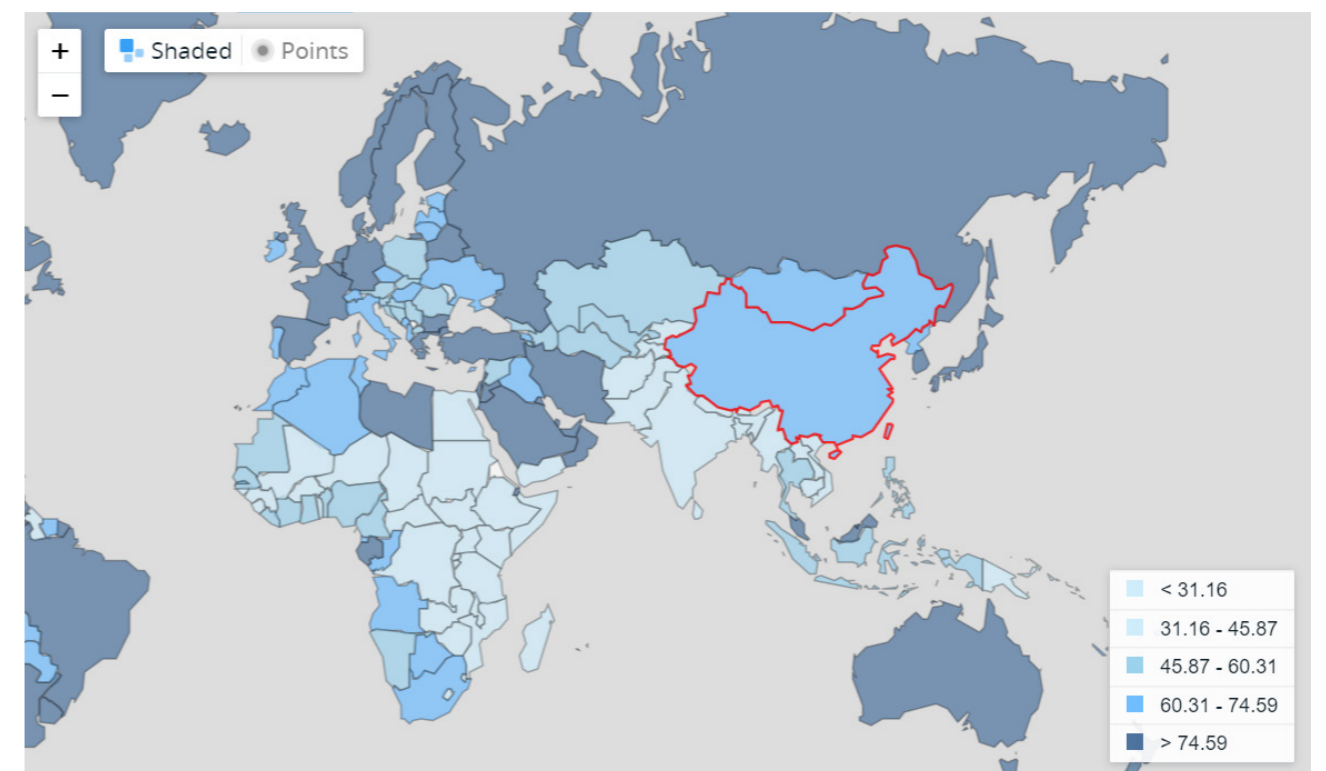

Fig.2.1.1 1982, 2000, 2015 and 2050 (estimated) Population pyramid of China

Source: National Bureau of Statistics, Evergrande Research Institute

http://finance.sina.com.cn/zl/china/2020-08-26/zl-iivhuipp0763201.shtml

Fig.2.1.2 1960 Urban population (% of total population) in China is 16.203

Source: World Bank

https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?end=2019&locations=CN&start=2019&ctype=shaded&view=map&year=2019
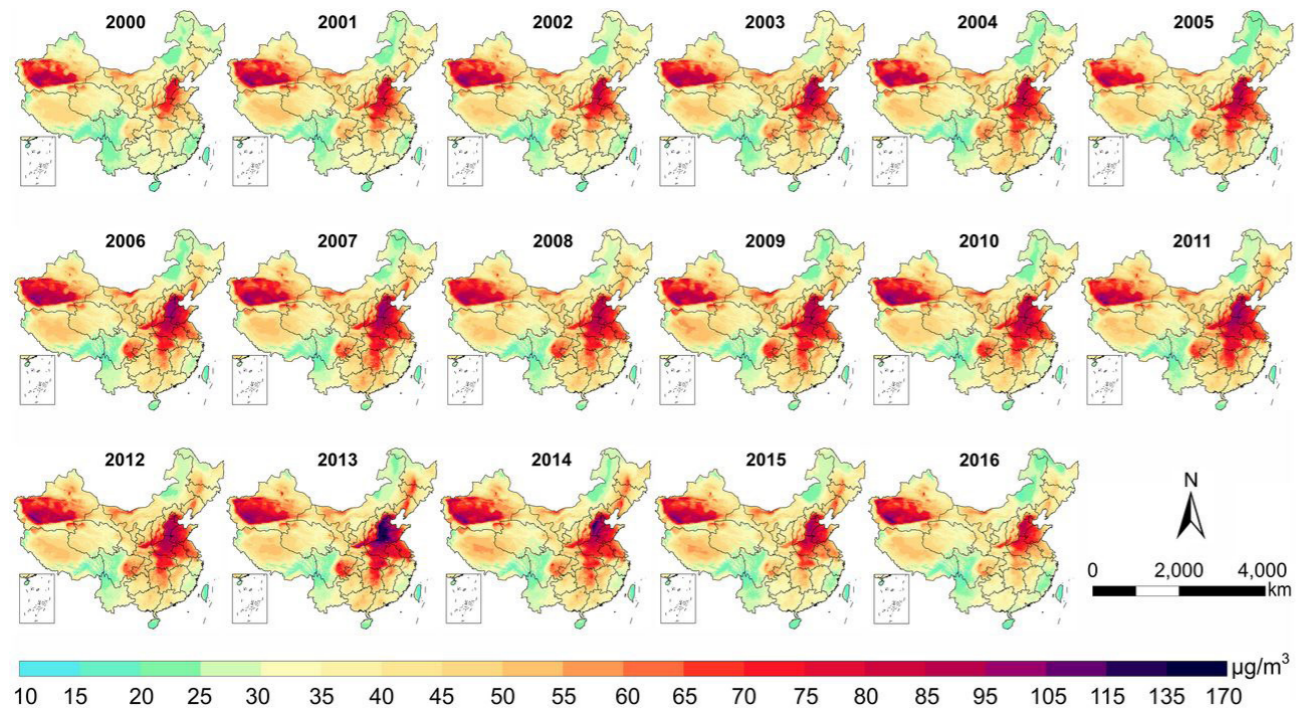

Fig.2.1.3 2019 Urban population (% of total population) in China is 60.308

Source: World Bank

https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?end=2019&locations=CN&start=2019&ctype=shaded&view=map&year=2019

Fig.2.1.4 Annual mean spatial distribution of PM2.5 concentrations in China from 2000 to 2016 at 1-km spatial resolution

Source: Proceedings of the National Academy of Sciences of the United States of America

https://www.pnas.org/content/117/41/25601

Fig.2.1.5 A person is in front of the Forbidden City in Beijing in a day badly hit by air pollution

Source: Kim Kyung-Hoon/Reuters

https://cn.nytimes.com/china/20150812/cc12ozone/zh-hant/
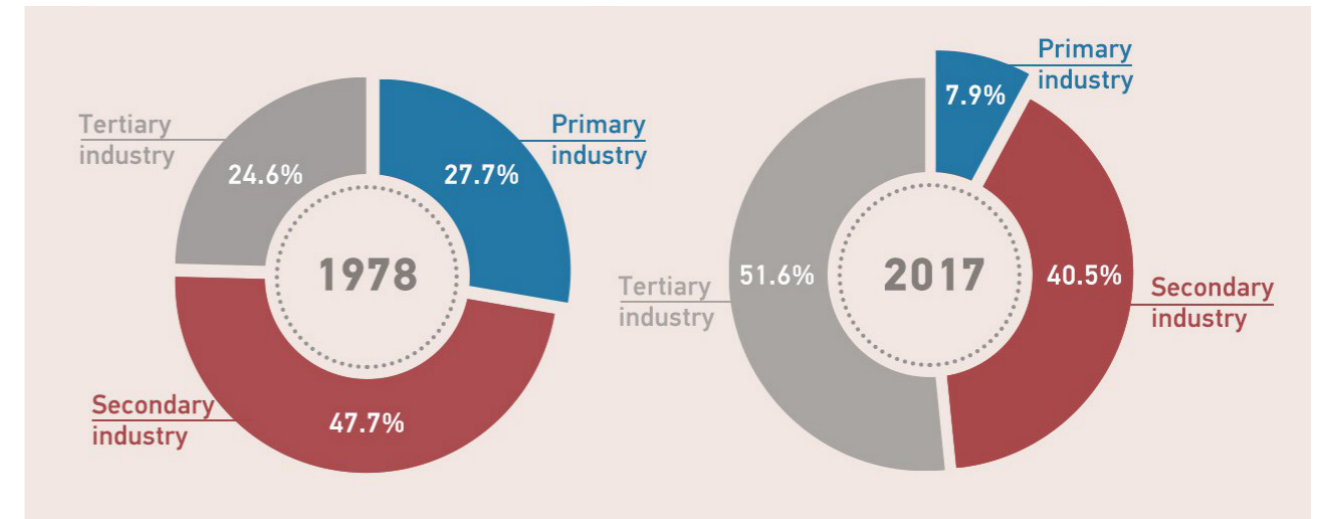
Fig.2.1.6 Composition of China's GDP by sector

Source: CGTN

https://news.cgtn.com/news/3d3d-674d77677a4d31457a6333566d54/share_p.html
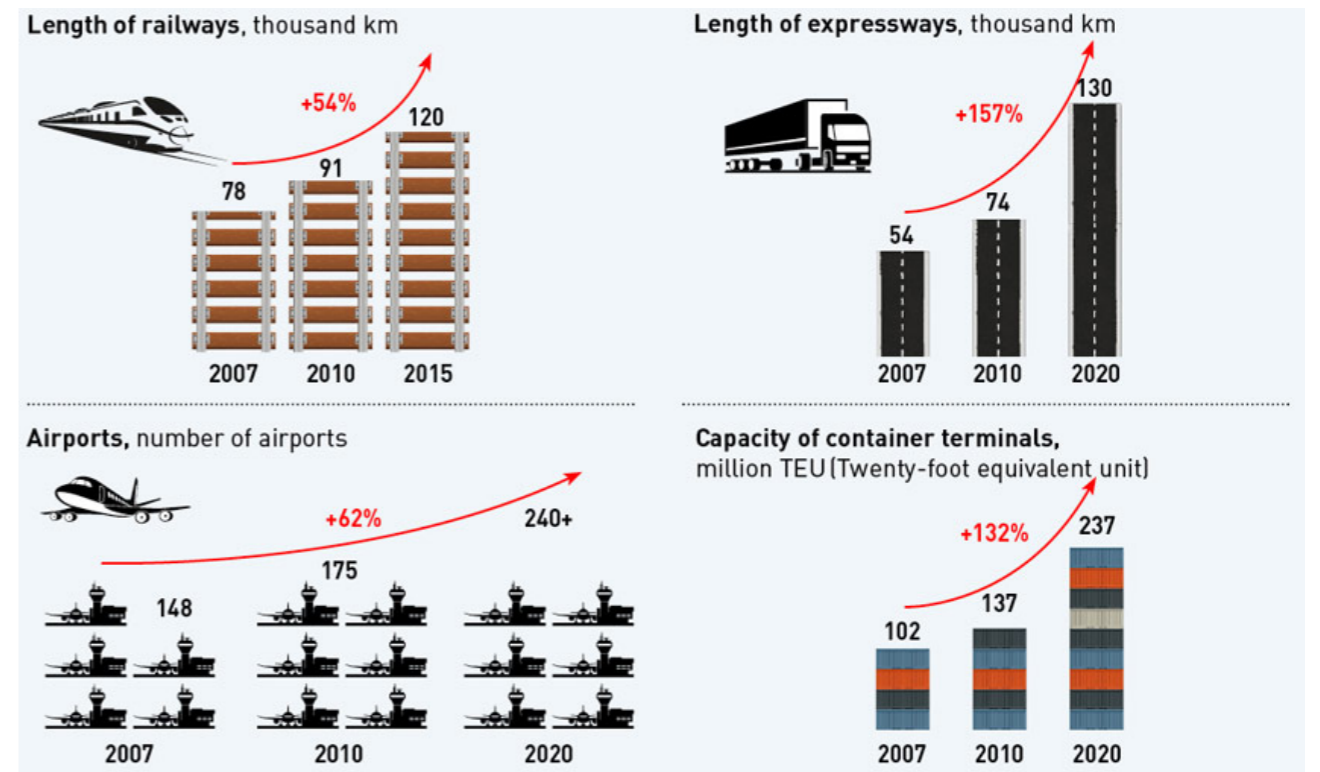
Fig.2.1.7 Building China

Source: McKinsey

https://english.ckgsb.edu.cn/knowledges/the-business-of-urbanization-in-china/

2.2 Technology - Based Urbanisation

Looking around Japan, South Korean, Singapore...the Party knows they can count on high-technology, it is their future, a future powered by high-technology and the engine does not heavily and only rely on non-renewable energy but data. Almost a decade later, in 2016, it is a critical year to this drastic shift and a Go match is the watershed in the history of Artificial Intelligence (AI) as well as in the Chinese history. Always played among the Chinese intellectuals in ancient China, Go is also a game by professional players today and regarded as the most challenging board game for AI because of its complexity*. It is not an ordinary game played by two players against each other, it is a historical match that took place in Seoul, South Korea in March 2016: the legendary Lee Sedol, widely considered to be the greatest player of the past decade. Famed for his creativity, he is the winner of 18 world titles**. However, this Go world champion was defeated by AlphaGo as the first AI computer program to master this classical game invented in China. According to Google, over 200 million** people watched this DeepMind Challenge Match online and witnessed its victory, 60*** million people in China are part of them. (Fig.2.2.1) Since then, Chinese have caught "AI fever" as described by Lee Kai Fu. (Lee, 2018)

Fig.2.2.1 South Korean professional Go player Lee Sedol and AlphaGo, during the Google DeepMind Challenge Match in 2016

Source: Handout—Getty Images
https://time.com/4257406/go-google-alpha-go-lee-sedol/

Go is a turning point and points out the direction for the Party. It inspired them how to visualise the future, where and how to set the goals for over 1.3 billion Chinese. The Chinese Government explicitly directs the national focus towards high technology, since 2015, AI is one of the major focuses. In parallel with other research and development for cloud-computing, 5G networks and so on, a lot of plans have been made to encourage and foster AI's development.

A year after the unprecedented game, The State Council of the People's Republic of China announced its first plan on AI in July 2017, instructing all provinces, autonomous regions and municipalities directly under the Central Government, all ministries and commissions of the State Council and all directly affiliated institutions, basically all its subordinates to embark on a new journey and a new reform to implement its policies on AI carefully (State Council, 2017). Supported by the Party, the temperature of the AI fever has even gone higher.

The power is absolutely centralised at Beijing but interpretations of the country's directions and its implementations are highly decentralised. Perfectly understanding the competitions of climbing up the hierarchy to reach Beijing from other cities are incredibly intense and fierce, locals' officials who are eager to strive for recognition among numerous counterparts would try all means to compete and show their efforts on a long list of spreadsheets represented in numbers. (Democracy At Work, 2019) Under such a competitive environment, officials give out all they can to encourage people to research and develop AI as the Party said. In Beijing, being the one of the groups of pioneers in creating the high-technology atmosphere and incubating the talents. Areas like Zhongguancun are designed for and dedicated to talents who are thirsty in being successful in the technological industry. Low rent or even rent-free incentives together with other favourable policies are adopted to attract them to come to the prime area in the capital, thousands and millions of like-minded people have formed the clusters ever since.

The same cutthroat culture and environment is found inside the technological arena besides the political circle. It is rather common to see those iron-willed warriors returning from foreign education to enter battlefields in China. Despite copying was the starting point for them, to copy the established industrial giants and leaders originated from the west, they quickly improved and learnt to develop their own recipes specially for the Chinese market and slowly debuted themselves in the international stage. (Lee, 2018) The gladiator type of competition pushes them to fight like no tomorrow, either to be buried inside countless of unrecognizable faces or to shine, attracting the attention of the venture capitalists or turning oneself as a technological tycoon. Such huge motivation drives them to be the crème de la crème to survive. Baidu, Tecent's, Alibaba, Huawei, ByteDance...that were borned and raised in China have been revealing their power towards the world. The combination of government, talents and venture capitalists have contributed a lot to the national transformation, they help the nation to enter a new data era.

According to the most updated release of the International Data Corporation (IDC) Worldwide Semiannual Artificial Intelligence Tracker, the AI market revenues worldwide, including services, software and hardware are forecast to grow 16.4% year over year in 2021 to US$327.5 billion. It is expected to reach an impressive US$554.3 billion* by 2024 for this market. For the Chinese AI market, based on the latest report published by Deloitte in 2018, it is expected to be RMB 71 billion by 2020 since its growth from 2015 with a compound annual growth rate (CAGR) of 44.5% from 2015 to 2020 which takes up more than 10% of the global market size. AI no longer stays inside the academic research laboratories and science fiction movies, it has reached an implementation stage, its implications are far-stretching and able to reach many aspects in life. (Deloitte, 2019) AI fever does not only affect researchers and entrepreneurs but finally starts to penetrate the life of a citizen.
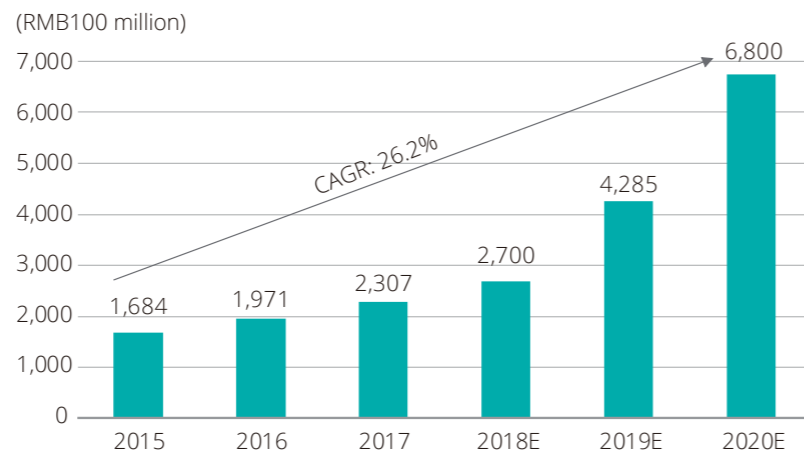
Fig.2.2.2 Global AI market size (2015 -2020)

Source: chvxx.com, Deloitte Research
Deloitte. (2019) Scenarios and Potentials of AI's Commercial Application in China. Deloitte.
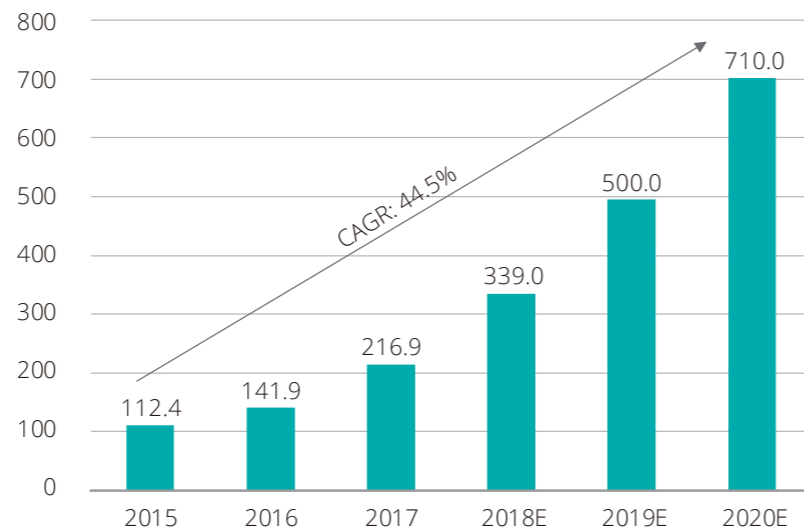
Fig.2.2.3 China's AI market size (2015 -2020)

Source: chvxx.com, Deloitte Research
Deloitte. (2019) Scenarios and Potentials of AI's Commercial Application in China. Deloitte.

Fig.2.2.4 The top AI companies in China by four segments

According to the 2019 China New Generation Artificial Intelligence Development Report, the AI landscape in China consists of more than 3,000 companies.Applications, Amalgamated Companies, Basis, and Technology are the four main segments and Inside each segment, there are groups based on the industry.

Source: Daxue Consulting "Chinese AI companies"
https://daxueconsulting.com/ai-landscape-china/

Fig.2.2.5 China AI Top 50

Two-thirds of global investment in AI is poring in to China which helped the AI industry there grow 67% last year alone. Among the top 50 AI companies to watch, including 14 "unicorns" - start-ups with a valuation of $1 billion or more - worth $40.5 billion in total.
Source: China Money Network
https://www.monigroup.com/article/meet-chinas-5-biggest-ai-companies

Drivers can see **traffic** jams before they happen.

🌐 IBM

Trains now queue for passengers.

🌐 IBM

Shirts can pick a tie for you.

🌐 IBM

Food is now followed from farm **to fork.**

🌐 IBM

Now every doctor **knows you** personally.

🌐 IBM

Buildings bring down their own energy costs.

🌐 IBM

In India, tiny loans can make an even **bigger** difference.

🌐 IBM

Police see emergencies before they emerge.

🌐 IBM

Any child can **access** a first-class education.

🌐 IBM

CHAPTER 3|

THE BIRTH AND RAISE OF SMART CITY

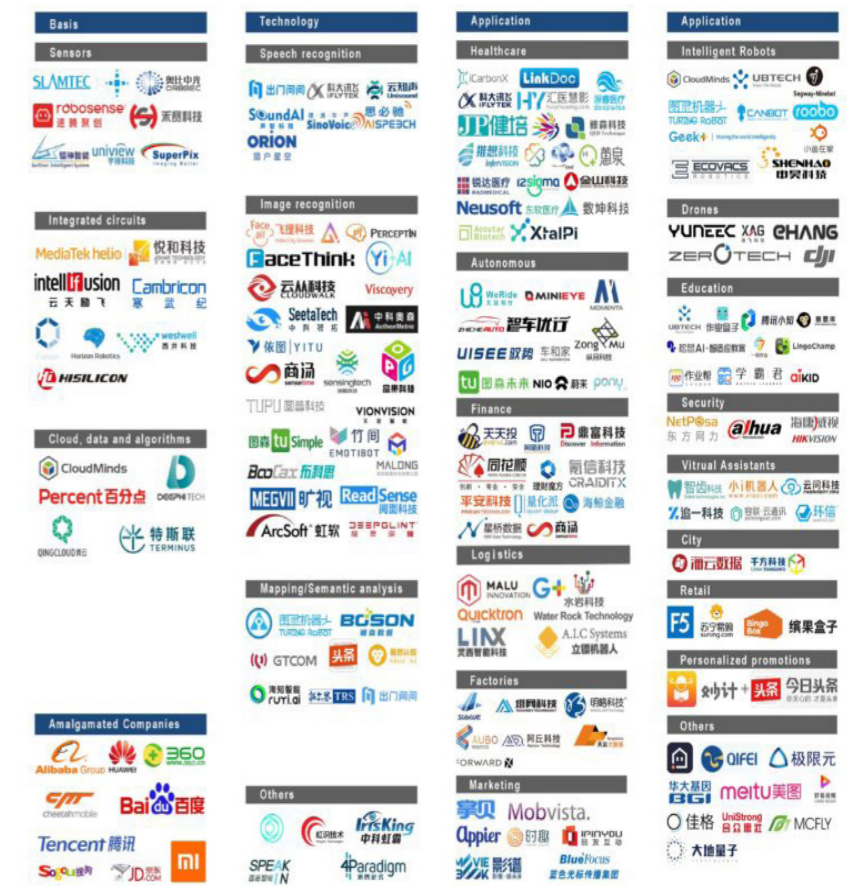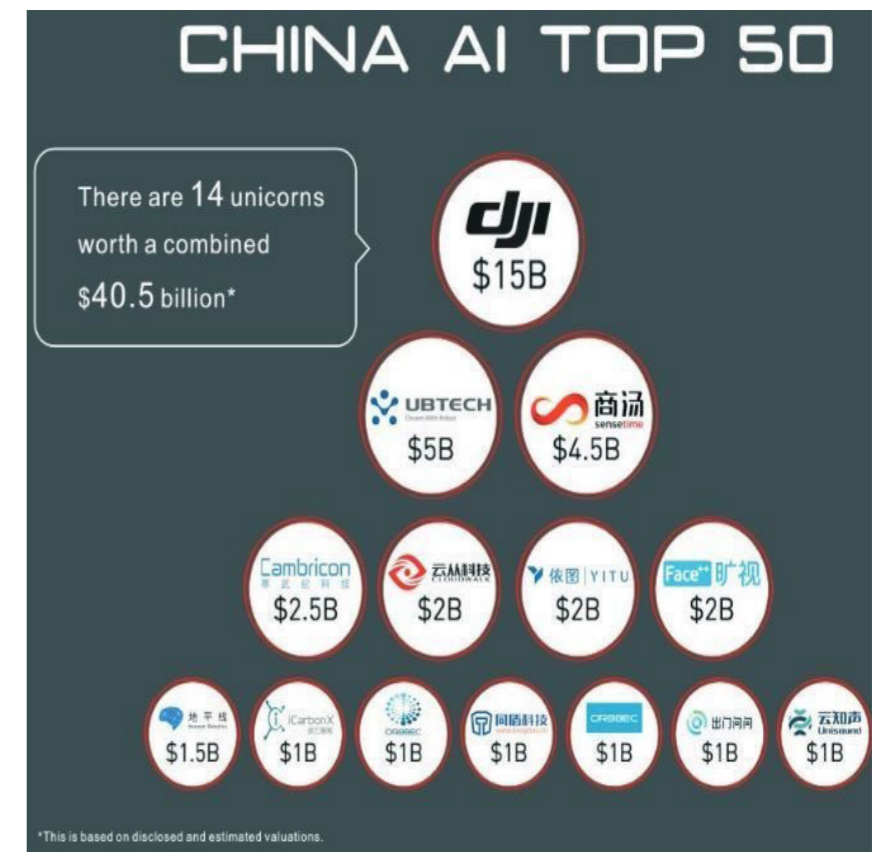The term smart city was coined in the United States of America, inside the business environment of two multibillion - technological companies, IBM and CISCO (Rosatia, & Contia, 2016). Initially, It was borned under the promotion of the public figures as the sustainability issues deserved more attention and private actions and talents to be involved. Since the "smart city" concept was formed, numerous attempts have been made to formulate the definition of a "smart city". One of the trails is by binding it with different terms which indicates the lack of a uniform or widely accepted definition (Schaffers et al., 2012; Zhuhadat et al., 2017; Chong et al., 2018). In publications concerning the subject of a "smart city", there are many alternative terms for this concept, such as: "digital city" (Tan, 1999), "wired city" (Targowski, 1990), "information city" (Fietkiewicz et al., 2017;Sproull & Patterson, 2004; Stolfi & Sussman, 2001), "ubiquitous city" (Shin, 2009), "sensing city" (Mone, 2015).However, in this paper, the conventional term "smart city" is used.

3.1 A Multifaceted Smart City

Countless scholars over the world have attempted to define the concept, some give an overview of the concept with a strong emphasis on the importance of the role of technology, some go further to explain without concerning other aspects, such as sustainability and humanity, only technology cannot make a city smart. Assuming that a city should be a creative, sustainable area that improves the quality of life, creates a friendlier environment and the prospects of economic development are stronger as a smart one (Lee et al., 2014). Intelligence as a distinguishing feature of this type of a city, should not be treated in the literal sense of the word but perceived as the sum of various improvements in urban infrastructure, resources and public services (Allwinkle & Cruickshank, 2011).

Added to its vast definitions, the meaning of "smart city" can be changed under different scenarios, not surprisingly, different actors would also interpret this differently. For example, "smart city" can also be taken or seen as a marketing strategy to refer to the use of technology in particular data collection to improve the functioning of cities. Yet, the most obvious commonality among the definitions is technology, for instance, the use of Information and Communication Technology (ICT).

IBM Smarter Planet Outcomes campaign posters

IBM launched a campaign called Smarter Planet in 2009 and teamed up with illustrator Norma Bar to design a set of posters. These award winning illustrations are used in the campaign running in major US newspapers and airports.
Source: IBM
https://www.pinterest.com/pin/81135230761633458/

IBM identifies three criteria to characterize a city being smart (Sajhau, 2017). Firstly, the presence of data platforms which can collect and aggregate a vast volume of data from different sources. Secondly, relevant information available at the regional level, in other words, data platforms must make it possible to redistribute useful information in an intelligible manner, data observed through open data and predictions made using analytics and cognitive computing. Lastly, citizen's participation in the process which can be active or passive with consent. Apart from the definitions made by the technological experts, authors and intellectuals do attempt to define the concept of a "smart city" focused on the technological aspect through publications. For example, Peng, Nunes, & Zheng, (2017) defined a "smart city" as a city using a set of advanced technologies, such as wireless sensors, smart meters, intelligent vehicles, smartphones, mobile networks or data storage technologies. Guo et al., (2017), claimed that a "smart city" is urban development based on the integration of many information and communication technology (ICT) solutions to manage the city's resources.

The role of technology is emphasised to define a "smart city" but a city can hardly become smart because of technology alone (Nam, & Pardo, 2014). "Smart city", defined by (Ortiz-Fournier et al., 2010) citizens are included in it. The authors described a "smart city" in the context of its intelligent inhabitants, the quality of social interactions and integration with public life. It is noticed that the needs and preferences of the inhabitants are highlighted in the current "smart city" concept and become the focus. Briefly, residents, their specific features and abilities are the basis of a modern smart city and their sentiments are crucial to an effective city management which shall be seen as a foundation for any policies planning and implementation.

Huang et al., (2017) also emphasised aspects of city management. A city is defined as smart if it is run intelligently, efficiently and sustainably. According to the assumptions of Manville et al. (2014), a "smart city" is one in which civic problems are resolved by using information and communication technology (ICT) in collaboration with city authorities and with the involvement of different types of stakeholders working with them side by side.

To conclude, cities can be defined as smart for many reasons in multifaceted perspectives and there is not an official and unique standard which is universally accepted and agreed upon across the nations, yet, there are some indicators and frameworks developed by scholars which are being widely applied when determining if a city is smart or not. One of the frameworks is discussed in this paper as part of the formulation of the overall discourse.

3.2 Smart Cities Evolutions - From Niche To Mass

It is not astonishing that like many other incredible, innovative ideas which are not completely novel. The history of "smart city" can be traced back to Los Angeles which has been pursuing computer-assisted data and policy research and analysis for decades since the 50s.(Vallianatos, 2015) Departments of planning and building and safety in Los Angeles mocked up computer punch cards in order to build up a system that they hoped would enable them to monitor, evaluate and analyze every piece of land there during the 1950s. In 1962, an idea to have "A Metropolitan Area Fact Bank for the Greater Los Angeles Area" was come up, a proposal was then submitted to the Ford Foundation looking for funding, thus releasing this idea.

Los Angeles was an advocate of adopting technology to the urban scale back to the 50s. However, the smart city concept would not be popularised without continuous efforts contributed by different parties on a global scale. Some critical events that drove the smart city movement are summarized in a chronological order to further understand its development:

The Clinton Global Initiative and CISCO

In 2005, aiming at solving global problems which affect the quality of people's life, The Clinton Global Initiative was launched by The William J.Clinton Foundation. To address some of the world's most urgent challenges, a community of global leaders were brought together by the initiative, to devise and implement innovative solutions and Cisco was one of those. In 2006, it dedicated 25 million US dollars over five years on technical research with a clear objective of how to make cities more sustainable. By creating pilot projects, Cisco collaborated with the cities of San Francisco, Amsterdam and Seoul to manifest the potentiality of the technology developed. For example, in Amsterdam, it started focusing on transportation virtualization and creative work practices by implementing Smart Work Centres, which enable local people to work in community centers in their communities without having to drive long distances. A smart Work Centre in the satellite town of Almere was opened to bring extremely powerful Telepresence technology for local residents, also including childcare, dining, banking, hot-desking and meeting facilities. For Seoul, the focus was placed on Personal Travel Assistant (PTA) which enables passengers to plan their journey in the minutest detail from their PC, a kiosk or even their mobile phone. Providing green route options became the first in the industry and interfaces with business applications, like calendars, thus ensuring professionals arrive punctually for meetings. In short, these are some of the innovative solutions implemented

to prove the concept that intelligent use of ICT based on pervasive broadband connectivity at a city-wide level can be beneficial to people's lives.

Right after the expiry of the programme, Smart and Connected Communities division was launched under Cisco to commercialise the products and services that it had developed during the past five years. Cisco's contribution has gone far beyond Clinton's commendation. Being a pioneer of researching sustainable solutions, Cisco continues to keep their mind on researching and developing technical know-how concerning sustainability.

Smarter Planet Initiative by IBM

Few years later, IBM, the IT giant, hatched similar plans. "Smarter Planet Initiative", a board programme to investigate the application of "instrumentation, interconnectedness and intelligence" which refers to the sensors, networks and analytics to some of the world's most urgent issues was launched in 2008. The subsequent year, IBM unveiled a 50 million US dollars "Smarter Cities" Programme which was put in an urban setting with a combination of technologies.

IBM explained how a whole new generation of intelligent systems and technologies would work more powerfully and be more accessible than ever before through its Smarter Planet vision. It could be used to make a significant impact and stimulate further thinking. Power grids, food systems, water systems, healthcare systems and traffic systems that are all smarter. Only with the cutting-edge analytics and algorithms to make sense of it all. Travel-centric transportation, consumer-centric electric power and intelligent systems for managing healthcare, water, public safety and food are some of the innovative ideas considered by forward-thinking leaders and global citizens. Hundreds of IBM clients seized new capabilities to develop smarter systems within a year of the Smarter Planet initiative's launch, they also started achieving measurable benefits for their businesses and communities. More than 6000 client engagements created $3 billion in revenue and double-digit growth for the Smarter Planet initiative in 2010. Smarter Planet ventures included mobile network, nanotechnology, stream computing, analytics, and cloud, according to IBM Research.

IBM launched the Smarter Cities initiative in 2009 aimed at helping cities operate more effectively, save money and energy, and boost residents' quality of life. In Spain, 8 hospitals and 470 primary care clinics introduced smarter healthcare programs through their facilities, resulting in reaching up to a 10% increase in clinical outcomes and operational efficiency. In a study of 439 cities, those that applied smarter transportation solutions cut travel delays by over 700,000 hours

per day on average. By observing consumer purchasing habits, aligning merchandising assortments with demand and creating end-to-end visibility across their entire supply chain, four leading retailers lowered supply chain costs by up to 30%, reduced inventory levels by up to 25% and increased revenue by up to 10%.

Throughout 2009, 100 Smarter Cities Forums were held by IBM around the world. Thousands of leaders were there to discuss how they should enhance the quality of life in cities, including making the best use of all the integrated data at their disposal. The 2009 Smarter Planet University jam kicked off a program to provide students with access to technology and training so that they can learn new skills and put them to work in cities globally. Through the Smarter Cities Challenge, IBM has deployed 800 top experts to support more than 130 cities around the world since 2010.

In 2010, IBM highlighted dozens of initiatives, shifting the focus from whether the technology can really build a smarter planet to learn how to get smarter operations up and running. During the year, the Smarter Planet initiative evolved into a multiplatform strategy involving marketing and sales channels, research and other disciplines, with the goal of promoting how IBM technology and know-how helps manufacturing, government, transportation, energy, education, healthcare, cities, and other businesses work smarter and contribute to the creation of a smarter planet.

Fig.3.2.1 Numbers of essay published in different newspapers such as The New York Times, Financial Times and The Wall Street Journal about the IBM's Smarter Planter initiative.
Source: IBM
https://cargocollective.com/lewwillig/IBM-Smart-Planet

Made with IBM is a campaign held in 2014 to showcase IBM's progress. Roughly six years after the debut of the Smarter Planet, it demonstrated IBM as an essential partner in providing technology building blocks for the new world at work, concerning data, cloud, mobile, social and security. A year after, an Outthink campaign was held to promote the concept of cognitive business. Ideas using analytics, natural language processing and machine learning are the aspects to be advanced in the Cognitive Era.

Smart City Expo World Congress

Smart City Expo World Congress (SCEWC) is the international summit of discussion about the link between urban reality and technological revolution. Organised by Fira Barcelona, since its first edition in 2011, it has taken place in the Gran Via exhibition centre in Barcelona every November (except the COVID situation changed the physical venue to the online platform). Succeeded to become a referential global event to support the development of cities, this professional, institutional and social meeting point is a leading platform of ideas, networking, experiences and international business deals that gathers together the highest level of stakeholders, in the context of urban development. (Lecha, 2011)

New technologies have dictated the concept of the "Smart City" but does "smarter" necessarily mean better? When are more sustainable cities sought? Ones that supposedly will offer a better quality of life. Who decides what technologies to use, and how to use them? (Fira Barcelona, 2011) All of these questions were raised during the first SCEWC edition, to discuss and to understand the interaction between technology and people and such a topic remains valid today, it even becomes more and more relevant every day.

The themes of the SCEWC changes every year but the efforts dedicated to the development of smart cities remain.

Smart city 1.0: Technology-driven
1999-2012

Features: led by IBM, Cisco and other major tech companies, focusing on problem-solving in different urban operation verticals through IT means

- **In 1999, Singapore announced its Intelligent Island initiative,** aiming at promoting the use of IT in areas such as urban energy consumption, traffic congestion and environmental pollution
- **In 2007, France initiated comprehensive development plans for Greater Paris,** one of which was reforming Paris' closed traffic network through intelligent management of bicycles with "Public Bicycle Management System"
- **In 2010, for the Portugal PlanIT Valley Initiative,** Cisco was tasked to develop an IoT ecosystem of connected smart devices and then integrate it into urban development process to tackle energy and waste management issues

Smart city 2.0: Government-led
2014-2016

Features: based on urban development requirements, governments formulate plans on the overall use of technological solutions to improve municipal operation efficiency

- **In 2013, London, UK** launched its first citizen-centered smart city plan to make city operation more efficient through the use of technologies
- **In 2014, the Korean government** put forth the idea of "Big Data for small problems" with an aim of building a people-centered, IT-driven smart city teemed with creativity
- **In 2015, the US government presented a new "smart city" proposal** with active plans for intelligent transportation, power grid and broadband to tackle urban transportation and energy issues
- **In 2015, India planned on building a hundred smart cities with PPP model.** Its government announced a 7.5 billion-dollar investment scheduled in the next five years for such development

Smart city 3.0: Society-backed
2017-now

Features: Governments give guidance and encouragement to citizens and companies for participating in the smart city development, serving the public through the use of data

- **Since 2016, Vienna has worked with local energy company WienEnergy** to encourage citizens to buy modules from the company and become investors of "citizen solar power plants"
- **In 2017, Amsterdam introduced competitive tendering for public utility projects in its smart city plan** to incentivize companies to participate in the building and integration of intelligent transportation and smart grid systems
- **In 2018, London announced the "Smarter London Together" roadmap** to improve life in city by allowing companies to participate in R&D activities and apply new digital technologies in smart city development
- **In 2019, Canada announced a plan to build a smart city in Toronto with a billion-dollar investment co-funded by companies,** which will be used to bring in necessary technologies and equipment

Fig.3.2.5 Development history of global smart cities and where they are

Source: Deloitte

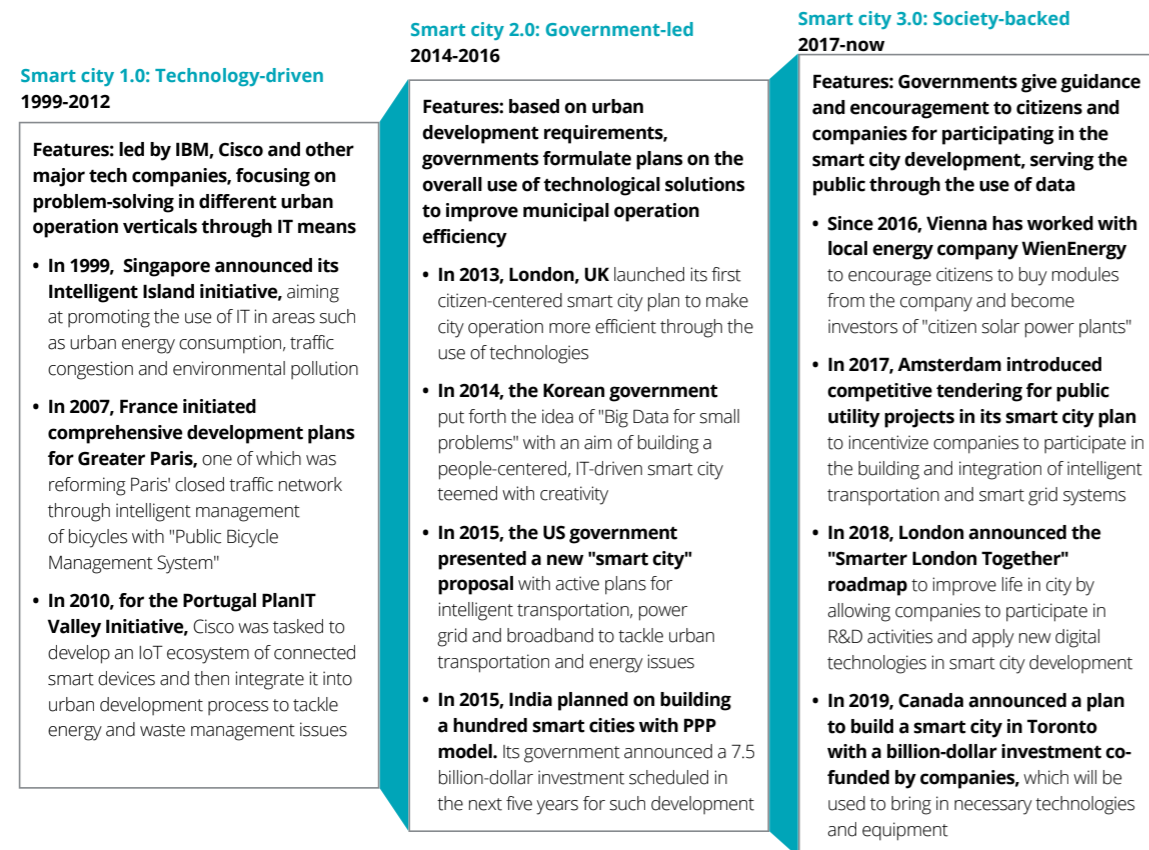Deloitte. & China Unicom. (2020) 5G smart cities whitepaper. Deloitte & China Unicom.

3.3 WHY TO BE SMART

As discussed, smart city covers a wide range of spectrum which somehow explains the motives and urges behind its diversified topics. No matter if one is a believer of Evolution or not, things keep evolving, mostly it is the result of the yearning for improvements or solutions. "When there's a will, there's a way." When facing problems, some would try to find out the answers, the same logic can be seen and found in the birth of smart cities: to combat problems. There are thousands of problems found and to face as living in cities, smart cities are hopes and solutions to some people.

Urbanization is expected to grow despite its rate having been slowed down because of Covid-19 (Fig. 3.3.1). Not surprisingly, such a rate varies among all the counties, yet 68 percent of the world's population is projected to live in urban areas by 2050 which is increased by 14 percent compared to the 2016's figure (Ritchie & Roser, 2018). Human beings are undeniably one of the crucial factors in this urbanization process. Given the need to search for better job opportunities and for a living or simply do not like the retired-like life, urbanization has always been a solution to many individuals or families (Fig. 3.3.2).

Resource is inevitable to sustain peoples' livelihoods, same for cities whose "livelihoods" also depend on resources. In other words, urbanisation further pushes the need for resources because of the constructions of cities. Since both people and cities demand for resources, the consumption for resources has been mounting up the demand for non-renewable resources which have been used to feed and fuel the cities. The environmental crisis is nothing novel since the early 70s, "thanks" to some environmental disasters, like global warming, ozone holes, acid rain and so on, the environmental awareness has gradually appeared in society. Such awareness has driven some people to look at the world at a different perspective, therefore, to change the way they live. Green architecture was born after that awareness. Modern movement in architecture favours the uses of concrete, steel and glass, besides the use of these non - environmental friendly construction materials, heavy reliance on mechanical cooling and heating systems of a modern building causes the surge of fuel consumption. Green architecture revisits the entire practice of the industry through research and development, resulting in innovative material, design and construction which is a clear example to show how people have reacted differently to the environment because of the crisis.

Even some hope for eternity, human beings who are bound by the Law of nature, grow and die at some point under normal circumstances. In a modern society, people do not accept nor allow the concept of decline let alone die in the economic sense. The legacy of the enterprises and more importantly profitability and growth are expected to be eternal. From nations to enterprises to businessmen, despite their size and scale, they all share the idea of constant growth and ultimately to maintain their wealth under the flag of Neo-Capitalism. Idea of eternal growth is perfectly elucidated by David Harvey through his writings, particularly the concept of urbanization of capital (Harvey, 1985).

Smart cities not only can be viewed as a commodity to market, to be packaged and ultimately to be sold, the potentiality is exponential when taking all the new business opportunities and industries created into account. Moreover, do not forget that new technologies can be invented and also can improve. Improvement in efficiency that smart cities can bring to the business and ultimately to the economy can never be overlooked. Smart city development worldwide will create business opportunities worth US$2.46 trillion by 2025, predicted by Frost and Sullivan*. Furthermore, more than 70% of global smart city spending will be from the United States, Western Europe and China by 2030. These figures communicate perfectly how lucrative smart cities are and how they can push the ideology of economic growth that many uphold tight, all these show the eagerness to pursue the research and development, eventually the extensive application of smart cities.

* https://futureiot.tech/smart-city-market-to-value-us2-46-trillion-in-five-years/#:~:text=Frost%20and%20Sullivan%20predicts%20smart,healthcare%20facilities%20as%20well%20as

Even though there are growing concerns over the social responsibility of business, social enterprises are also nothing new nowadays, they take care of a lot of aspects which are too trivial or even unattractive to some companies, however, it does not mean that all the capitalists give up their beliefs on profit-maximization. Similar logic can be applied to look at the phenomena of social control in the political sense. Human rights are very much appreciated and valued by the majority. Although political systems vary among nations and sometimes cities, it does not mean that social control no longer exists in any regime around the globe. The truth is social control no matter how it is done, somehow history and reality prove that it has to be done, the reasons are diverse, they can be protecting the individual citizen from crime to safeguarding the stability of a nation or simply the people with power. The real underlying motive can hardly be argued but data collecting, video tracking, facial recognition and so on are the veracity of the modern - day practice done by the government. Developing the smart cities infrastructure can undoubtedly facilitate the effectiveness of social control.

In parallel to the social-control controversy, some officials see opportunities in developing and expanding the entire idea, economical motives are obvious to some while some have seen its potentiality to encourage more social interaction and participation in operating and visualising the city. Hoping that people can voice out their ideas and comment on the place where they supposedly know very well and have a certain emotional attachment. Such a bottom-up approach perhaps is seen as improbable but it has been tested and encouraged in some parts of the world. If the government believes in the vulnerability of people's participation to a future city, smart city is not an exception but another tool to achieve such an objective.

Share of the population living in urban areas, 2050

Share of the total population living in urban areas, with UN urbanization projections to 2050.

| No data | 0% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
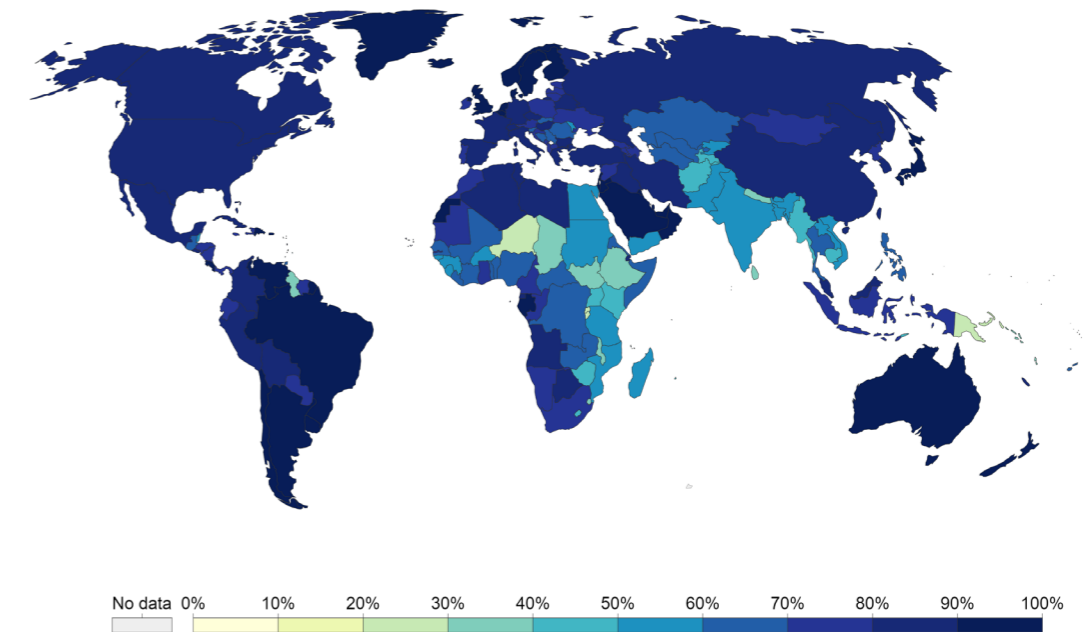
Number of people living in urban and rural areas, World, 1960 to 2017
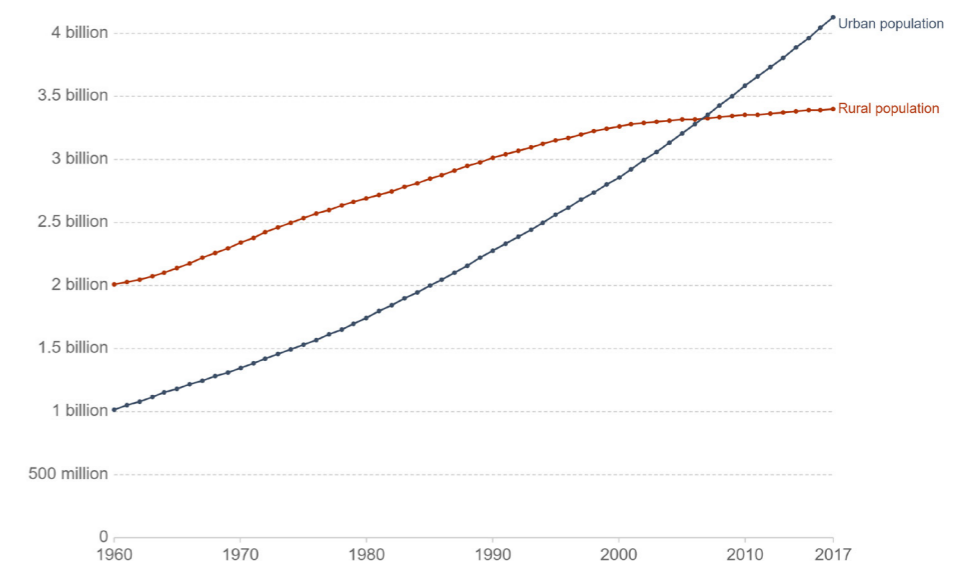
3.4 HOW ABOUT IN CHINA

EVOLUTIONS

China's smart cities initiatives are somehow a culmination of longstanding Chinese policy trends and seen as components of a broader Chinese approach to information policy that seeks to link military and civilian information technology development aiming at increasing China's comprehensive national power. The development of smart cities in China can be seen and classified into three stages: infancy, exploration and the emergence of new smart city models (Fig. 3.4.1). (Deloitte. & China Unicom. 2020) Priorities are set by central authorities but pilot projects and other forms of experimentation are common at the local level, therefore, "Chinese model" of smart cities development portrays its distinctive characteristics which is the way it couples centralization of decision-making with decentralization of implementation. Transportation, public utilities, public safety, education, healthcare, and environmental protection are all common areas to focus for Chinese smart city initiatives according to Chinese municipal authorities in charge of smart city development. (Atha et al., 2020)

Although Chinese smart city strategies have emerged from previous informatization policies over the past few decades, the complexity of those policies in each preceding time is important to understanding the present situation. Before 2010, Chinese smart city initiatives were driven mostly by technology, lacking in top-level design and consistent planning. Digitalisation, supported by urban networks and data infrastructures, was the emphasis of the infancy period, with the use of remote sensing technology, geoinformation technology and global positioning system for data collection and monitoring. (Deloitte. & China Unicom. 2020)

Starting in the 1990s, "digital cities" policies concentrated on the State Bureau of Surveying and Mapping, the now-defaulting Chinese government agency dedicated to the monitoring of domestic cartographic activities that has grown its portfolio over time with emerging digital research and mapping technologies. Geographic information systems (GIS), global positioning systems (GPS), and remote services (RS) are the key focus of what is called in China : the "3S" technologies which was an effort to extend the spectrum of data made accessible and available to government policymakers. (Jin, 2017)

The idea of "information cities" centered at the beginning of the mid 2000s on "informatization" cities was incorporated into a broader scope of existing government frameworks, in other words, introducing municipal administration and urban infrastructures to the digital age, for example, by connecting those networks with information technology and modernizing telecommunications infrastructure.

Followed the "information cities", "Smart cities", through standardization and interoperability, seeking to facilitate the transfer of data among these government information systems, while gathering new types of data using advanced information technologies and allowing a wider variety of government actors to have access to information pertaining to their tasks and decision making.

Since 2010, development plans for smart cities were published and several rounds of pilot cities for experimentation were announced in China during the exploration phase. (Deloitte. & China Unicom. 2020) "New Smart Cities", the dominant current mode of the smart cities conception, refers to the introduction and adoption of new generation of information technology including Internet of Things (IoT), cloud infrastructure, pervasive telecommunication networks and big data technologies, to enhance urban planning and governance intelligence level and automation standard were mentioned in 2015. (National Development and Reform Commission, 2014) 13th Five Year Plan was published a year after, emphasizing that new types of smart cities should be developed and priorities must shift from exploration to implementation.
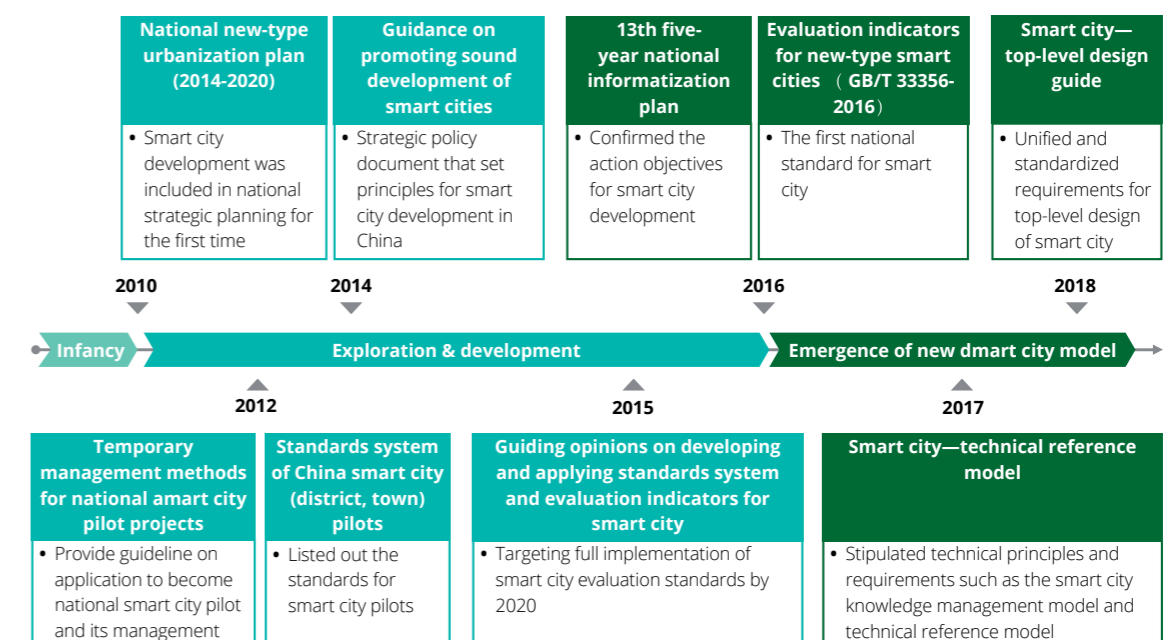

Fig.3.4.1 The development trajectory of Chinese smart cities

Source: Deloitte

Deloitte. & China Unicom. (2020) 5G smart cities whitepaper. Deloitte & China Unicom.

In 2018, Smart City – Top Level Design Guide was published covering and explaining the design concepts and realization process. Unified the requirements of top-level design, it also stated that development of smart cities will be safeguarded by the digital technologies that make cities smarter. Running simulations to guide the development of smart cities by building "Digital Twin Cities" parallel to the actual world.

To conclude, the technologies underlined during the previous phrase were not superseded by each phase of programmatic growth but to be inclusive for the latest edition (Yu, & Xu, 2018) Municipal and provincial pilot projects mostly coexist with national initiatives at "former generation" level before being extended or scrapped in accordance with their results. Very often, policies are mainly national when first being announced, followed in due course by more tangible and impactful steps because more granular directions to reflect on (Fig. 3.4.2), thus to interpret the meaning of abstract statements from top leaders are given by central government bodies.

Policies and projects initiated under the banner of one era may carry into the next era and thus be re-labeled, it is noticed that in view of the omissions or shortcomings in execution of the previous version's policies, each step of Chinese urban information policy has attempted to proceed correctly while taking account of changes in the technologies and resources which become extensively available overtime.

Fig.3.4.2 The smart city policies and years of publication by local governments
Source: Deloitte
Deloitte. & China Unicom. (2020) 5G smart cities whitepaper. Deloitte & China Unicom.

SMART DRIVERS

The official objectives of China's smart cities projects include common even universal innocuous goods, like, improved security and productivity, increasing the government's agility and perhaps reducing emissions, at the same time, the smart cities systems can also be designed to serve for social control. (Rajagopalan, 2017)

Certain aspects of smart city policies would eventually support Chinese government recognizing and eliminating any potential danger to regime stability. Smart cities projects provide a digital back-backbone that enables the consistent introduction of social regulation policies, such as social credit initiatives. The current smart city construction practice in China and President's emphasis on the subject in his speeches and policymaking represent perhaps the pinnacle of China's efforts to "informatize" its cities' governance and management for the next two decades. (Wu, & Liang, 2018)

Described as an incentive to incorporate information technology into all facets of government and society to develop China's comprehensive national power and internal strength. China's civil information policy was structured to meet national security interests. They function as one part of the wider whole as the latest strategy in a long string of "urban informatization" policies. This wider universe of information policies considers many industries, for instance, including plans for "smart manufacturing," which are anticipated to increase the production capacity thanks to information technology.

In line with several influences, including state-of-the-art, global and domestic technology developments, China's assessment of prevailing policy trends abroad, the assessments made by the Chinese Communist Party regarding the role that technology plays in retaining control of the Party and its internal stability, Chinese urban informatization policies have continuously developed and evolved. Throughout decades, as explained, it has progressed to "information cities" of the mid-2000's and more recently emphasizing on the "smart cities" and even " new smart cities" from the "digital cities" initiatives founded in the late 1990s. (Yu, & Xu, 2018)

3.5 HOW TO LOOK SMART

Inspired by Professor Rudolf Giffinger and his European Smart Cities research group at the Centre of Regional Science of Vienna University of Technology, renowned urban strategist and smart city expert Boyd Cohen developed an idea called "Smart Cities Wheel" which has been widely adopted (Cohen, 2012), the concept regarding the six key indicators is consistent with those suggested by Gigginger and his research fellows but he has further popularized it. The six key smart city indicators serve as pathways towards constructing a real smart city, smart government, smart economy, smart environment, smart living, smart mobility and smart people are the six key strategic action fields needed to be considered, developed and eventually be advanced. In short, they began as a strategic perspective as a direction but they shall not be forgotten as a holistic strategy to stimulate and to push actions.
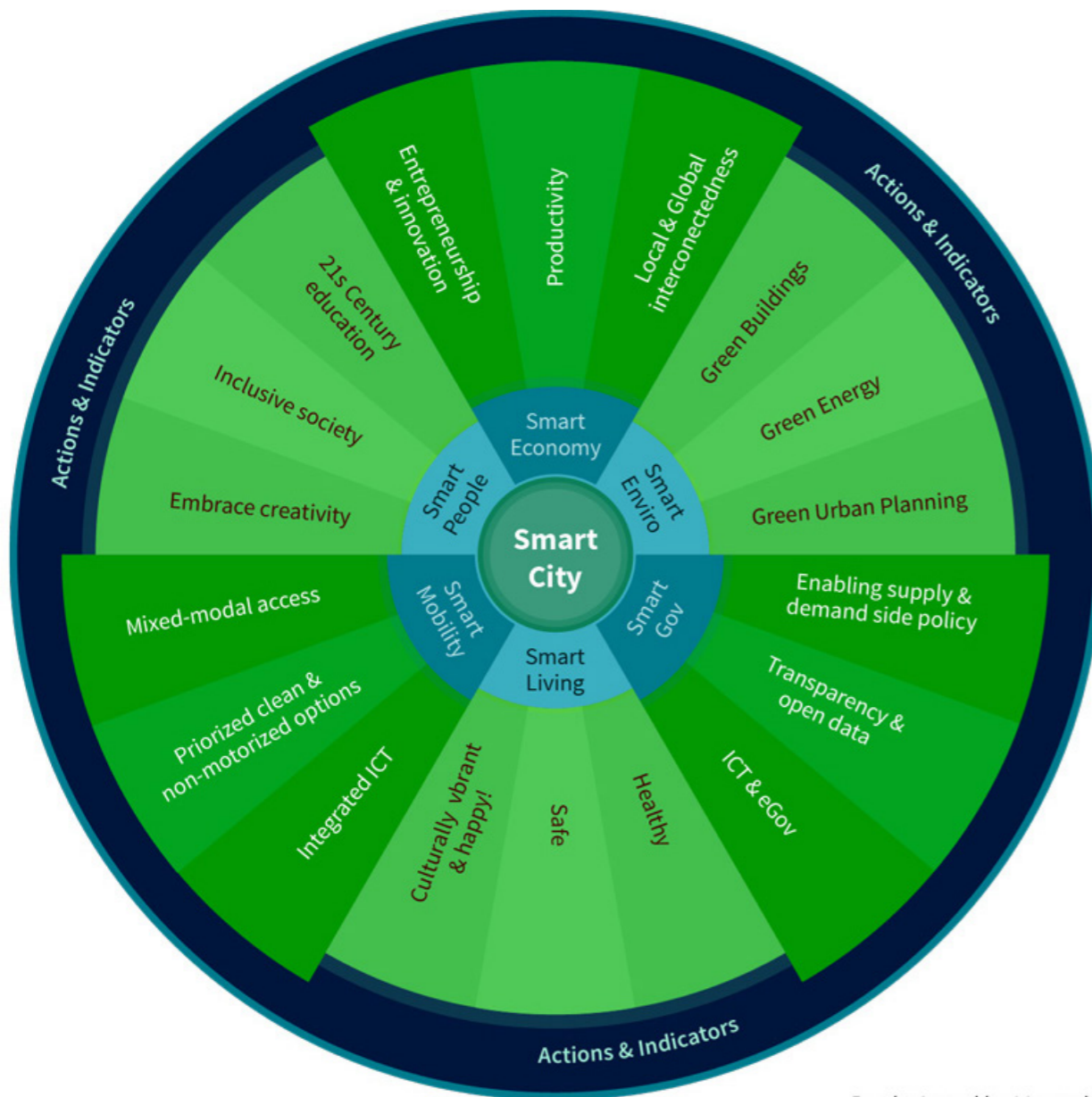
Re-designed by Manuchis.

Smart Government

Online services, infrastructure and open government are the main concerns under smart government which means connections and interactions between the government and all stakeholders including citizens, business and other organizations of the civil society within a municipality can be strengthened though implementing innovative methodologies. Openness of the government is possible to be achieved with clear objectives and actions. Constructing appropriate infrastructures promote the utilization of online services, in return, the government's accountability, responsiveness and transparency, also the needs and aspirations of the community can be underlined effectively and promptly. Smart city strategy can aid the government to reconsider the existing services provided for citizens and businesses regarding quality, scale and scope. As the name suggests, technology surely plays a part to develop the smart government, up-to-date and creative methodologies, for instance co-creation, crowdfunding or applying pioneering technology to any feasible aspects. If the smart target is set properly, considering the primary duty of a city is to serve people, the government can ultimately benefit from the smart measures implemented aside from looking at the domestic sense, the vitality and competitiveness of a city can also be fostered in the global stage.
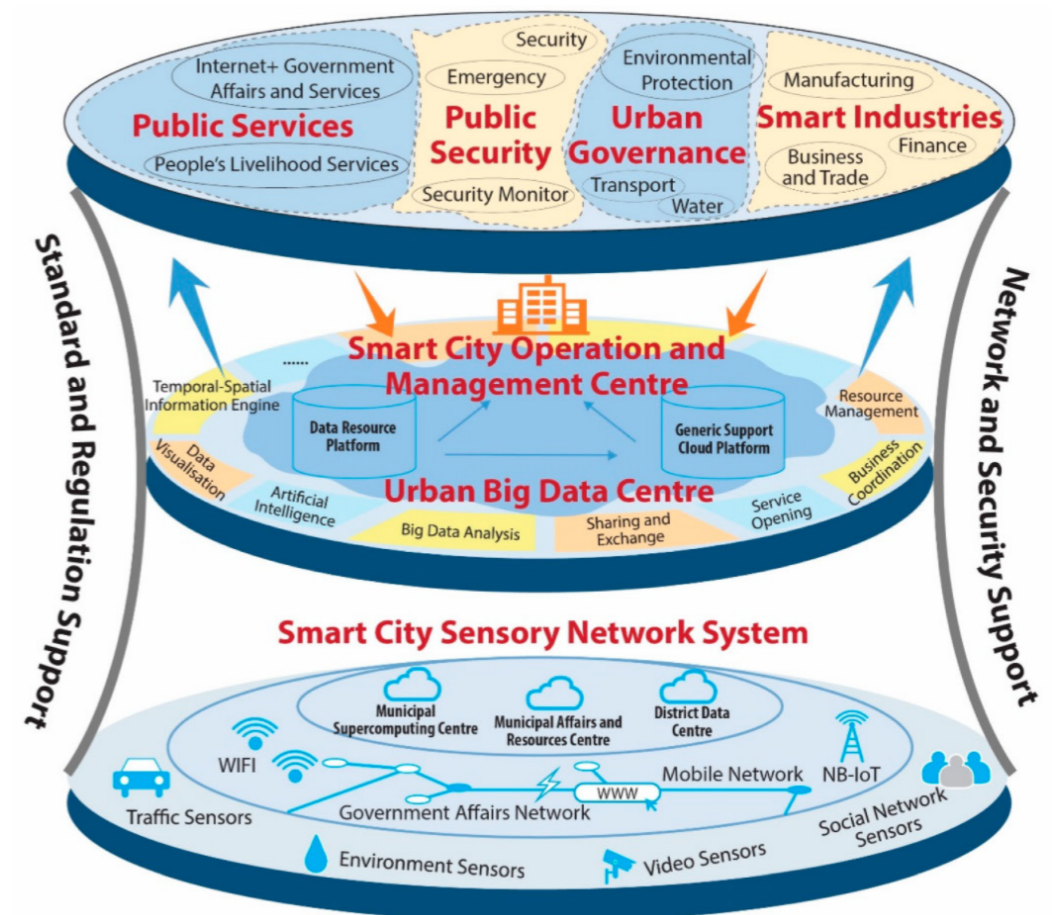
Smart Economy

Opportunity, productivity and local and global interconnectedness are the main concerns under smart economy which refers to transforming and strengthening a city's economy accompanied with all necessary actions. Growing the economy in a ground-breaking at the same time sustainable way, advocating innovation entrepreneurship followed by improving a city's attractiveness for start-ups, businesses, investors and fresh talents, developing advanced and sophisticated technologies and so on are some actions to be taken to enhance the overall business climate, such as encouraging production and services automation and developing new markets for invented services and products, all these to uplift the competitiveness of the economy, as a result, stable and favourable conditions for all parties concerned can be generated, ultimately economic prosperity is achieved with help from technology and intelligent approaches. Technology is a significant tool to seize the opportunities, by using the technology properly and wisely, it provides favorable conditions and other advantages to support and to grow the business, the wider economy in the local area and even beyond.

Smart Environment

Smart buildings, resources management and urban planning are the main concerns under smart environments which improve livability for the people. The wellbeing of the planet is not neglected or given up to the peoples' development but being protected, both the built and natural environment are managed carefully by the government addressed by the smart environment. The implementation of green urban planning, including regulatory and cultural changes that facilitate sustainable standards and practices can be supported by again using new and creative technology and creative methodology. For example, to fully understand and analyse the distribution of public spaces, grassland and green belts, thus to promote a green environment, can be done by using web-based and remote monitoring technologies. Furthermore, to improve efficiency at the same time to minimize the adverse environmental impacts can be achieved through setting new urban planning standards, a resilient community is not a dream but a feasible long-term mission. In short, a smart environment ideology embraces a wide range of goals, like accelerating the local energy transition, achieving energy efficiency, water management, emission reduction, monitoring and managing pollution and the reduction of waste production.

Fig.3.5.3 Each sapling has a QR code "ID card", which links to the Xiongan Forest Big Data Construction and Management Platform.

Source: Ma Mendi, kknews

https://kknews.cc/society/v59mral.html

Fig.3.5.4 AI together with other technologies are used to build "pig face recognition" + intelligent feeding machine for a smart agriculture system

Source: JD

https://www.36kr.com/p/1724642066433

Smart Living

Culture and happiness, safety and health are the main concerns under smart living, the goal is as simple as to increase the quality of life for all. Optimizing the management together with facilitating livability of the living environment by following an inclusive strategic approach across all age groups and demographics, addressing both of these aspects, thus to maximize benefits for all the stakeholders. Many focuses are highlighted for improvement, for instance, smart buildings, housing conditions, safety, healthcare and care for the elderly, social and digital inclusion including the use of electronic services and social media. Internet of Things (IoT) based on WiFi or Low Power Wide Area (LPWA) network technology, these new technologies can be leveraged to enhance users' experiences and accessibility, civic and social engagement can also be enhanced using new methodologies.

Smart Mobility

Mixed-modal access, clean and non-motorized mobility and integrated Information and communications technology (ICT) are the main concerns under smart mobility. The objectives lie in providing high-quality mobility services for everyone, also for everything and ultimately, improving the flow of people and goods within the city while reducing the burden on the environment. The preliminary key to success of a smart mobility strategy is to set-up and to adopt a people-centric and inclusive approach before rolling out the initiatives with the new and advanced technological help. Many measures, such as applying mobility management efficiently and adopting targeted infrastructure investments, plus other technological based solutions, including the use of video surveillance and remote detection technologies, can be done to increase the service quality and efficiency of urban transportation, to enhance the usage of new mobility solutions and to increase mobility of the people. Those technologies not only can monitor traffic facilities and analyze the data for managing traffic flow, pedestrian flow and cargo flow in real time, emergencies can also be handled. Despite integrated multi-modal transportation being a challenge for communities and cities, it is far too significant to be neglected but to tackle to obtain a more economical, quicker and greener mobility. Eclectic vehicles, hydrogen-powered vehicles, autonomous vehicles, bike sharing, carpooling or car-sharing…these new forms of transportation deserved more attentions and supports as they are crucial to implement a combined multiple modes of public and private transportation system, what is more, they shall be treated as part of the future-oriented strategic approach to foster "Smart Mobility".

Smart People

Education, inclusive society and creativity are the main concerns under smart people. People are valuable resources to a society who need to be treasured, they contribute to the development of information technologies and innovation, favourable environment for lifelong learning, labour market opportunities, vocational training…where social plurality, flexibility and acceptance are promoted have to be nurtured constantly, therefore to cultivate the talents and to retain them. Educational offers are a significant prerequisite for providing technological-based service and information efficiently which are also crucial to create a social and digital equality among citizens. The creation of an accessible and inclusive environment fosters innovation within a community and city in return for prosperity and harmony which shall be the fundamental beliefs of smart people' solutions. To sum up, information and technologies provide ground-breaking ways for people to interact and to participate is beyond doubt a transformation, again, smart forms of education is pivotal for such a successful transformation to take place as people have to be equipped with necessary knowledge and abilities to cope with any unprecedented and drastic changes as well as uncertainties.

Fig.3.5.5 A robot named Keeko was "teaching" the kids at a multicultural and educational institution next to Beijing

Source: Visual China

http://news.china.com.cn/txt/2018-09/14/content_63434183.htm

CHAPTER 4|

THE BIRTH AND RAISE OF AI

In the last chapter, it shows that smart cities are unquestionably a part of the digital revolution, among all the smart cities related conversations, topics about data and information have successfully attracted stronger and stronger spotlights over the decades. Even before all the disruptive technologies have penetrated into our lives, we left marks on earth every day, imagine the clothes we wear ,the food we buy or simply the smile we give to the others, countless and countless of data has been generating every second, yet, because of them, the collection of data, later on, the analysis process has turned from impossible to possible, unmanageable to manageable and very likely such process is becoming more and more affordable at the same time powerful. Looking at the massive amount of data, artificial intelligence becomes inevitable in the smart cities' discourses.

4.1 An All-round Artificial Intelligence

The term artificial intelligence first coined by Stanford researcher John McCarthy in 1956 who is said to have chosen it for its neutrality to avoid highlighting one of the tracks being pursued at the time for the field of "thinking machines" that included cybernetics, automata theory and complex information processing (Marr, 2018) (fig.4.1.1). In the same year, a group of researchers with a variety of backgrounds including language simulation, neuron nets, complexity theory and so on were invited by McCarthy to the Dartmouth Summer Research Project (now called The Dartmouth Conference) which is a summer workshop on Artificial Intelligence, to discuss what would ultimately become the field of AI (Hammond, 2015).They also came together to clarify and develop the concepts around "thinking machines" which up to that point had been quite divergent. "The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it." (Dartmouth. 1965) Such an insightful statement was stated in the proposal for the conference.

Vincent van Gogh-inspired Google Deep Dream painting

Alphabet Inc.'s Google put on an art show and auction called Deep Dream: the art of neural networks, with the Gray Area Foundation, a San Francisco not-for-profit organisation that fosters collaborations between the arts and technology in 2016. The priciest artwork receiving an $8,000 USD winning bid.
Source: Google
https://mk0caiblog1h3pefaf7c.kinstacdn.com/wp-content/uploads/2019/09/deep-dream-google.jpeg

Artificial intelligence being a sub-field of computer science, its goal is rooted in the development of how machines can imitate human intelligence, thus, to do the things associated with people acting intelligently, in other words, being human-like rather than becoming human are the focus of the modern dictionaries' definitions. The Cambridge Dictionary defines it as "the study of how to produce machines that have some of the qualities that the human mind has, such as the ability to understand language, recognize pictures, solve problems, and learn." Like the previous definition, Collins defines it as "a type of computer technology which is concerned with making machines work in an intelligent way, similar to the way that the human mind works." Unlike them, The Oxford Advanced American Dictionary adds the idea of copy inside the definition "an area of study concerned with making computers copy intelligent human behavior".

Two sub-concepts are combined to make up a full concept of Artificial Intelligence: (Cugurullo, 2020)

Artificial is commonly used to describe something that does not arise from a natural process which can be man-made or machine-made, both normally on purpose. Whenever it is made by people or machinery, the outcome or product manufactured from the process is called an artifact. Ranging from touchable to untouchable, from sizable to portable, they appear in a multitude of shapes, a television, a computer, a plane...most of the products we rely on today can be therefore considered as artifacts. Most of the AI we "see" is embedded in an artifact so to perform its tasks, depending on the goals and functions, an artifact varies to suit the performance and execution of those tasks. For example, an ordinary trash bin or a trash bin connected to AI which facilitates waste management, in this scenario, a trash bin is an artifact for AI to reside to do its work, cars, drones and robots are other popular artifacts for AI.

In contrast to artificial, intelligence does not have a rigid definition and it has always been subject to debates throughout history. Rather than concentrating on this arguable topic, it is more relevant to focus on what skills and capabilities intelligent entities are supposed to comprehend how intelligence manifests itself in AI and leave the questions of what intelligence is to the philosophers.
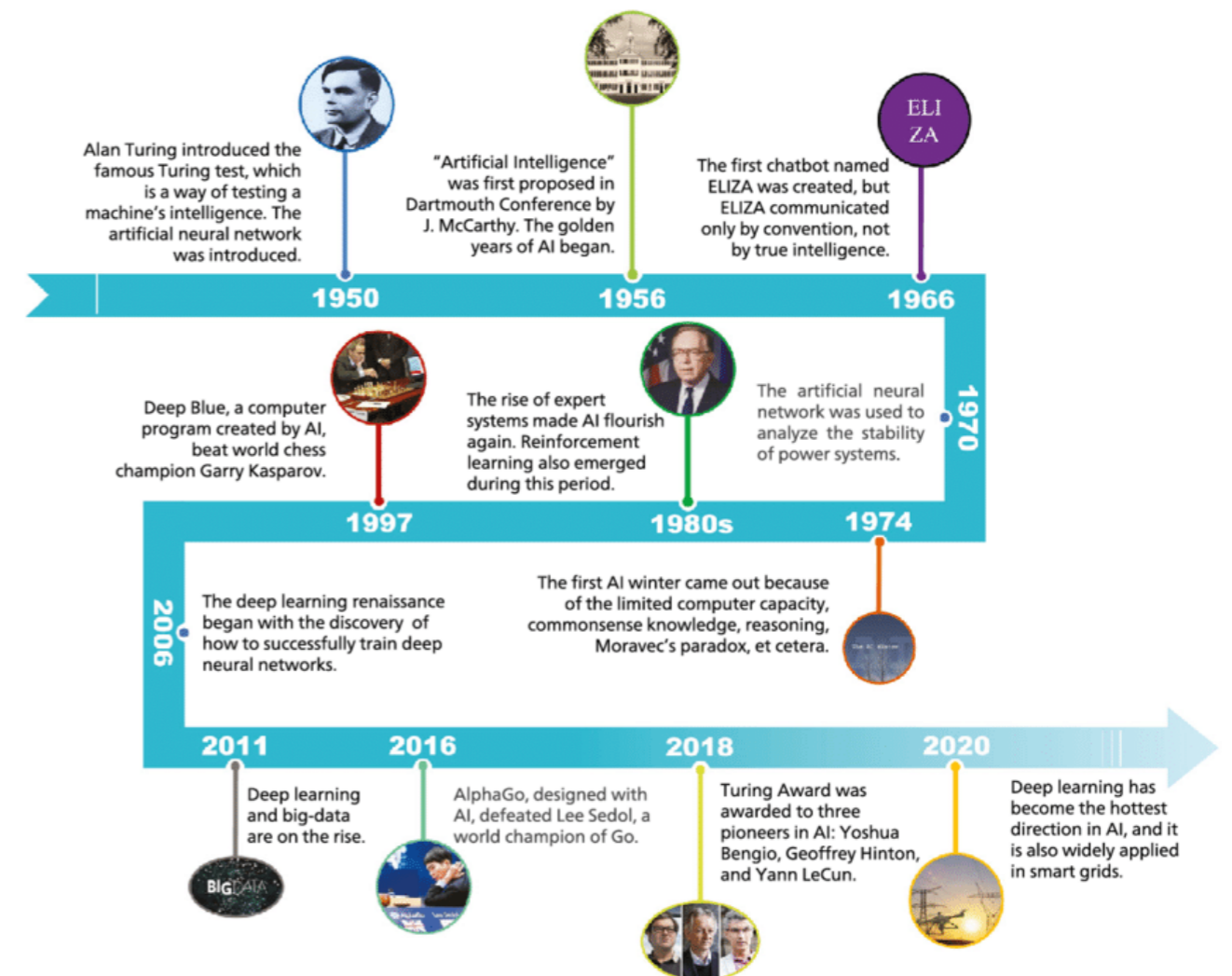
Firstly, being capable of learning by acquiring information from the surrounding environment shall be a fundamental quality that an intelligent entity possesses. Again, AI can learn directly or indirectly with the aim of gaining knowledge. Using the equipped cameras and microphones to sense the environment or data is fed by people, either way, AI learns.

Secondly, having an ability to understand correlation and a capacity to rationalise the acquired data by extracting from acquired concepts. For instance, AI extracts from visual data capturing the sunset when having a concept of evening in mind which is a straightforward example or it extracts from visual data showing kids are playing in a park when having a concept of joy, in this case, it is a more abstract concept about sentiment. Ultimately, the second quality allows AI knowing how and what to get relevant data needed for later analysis.

Thirdly, knowing how to handle uncertainty. Uncertainty is a state of being uncertain and uncertain means when the situation is not known or definite, in other words, this is an ability to tackle a problem or to finish a task, even if some information is absent or the data is fragmented and unclear. Imagine facing a situation which has never happened before, none is able to give you advice and suggestions on what to do but you can still cope with this situation, it is a sign of having intelligence. Developed by Google, in 2016, AIphaGo defeated Lee Sedol who is the world Go master is a very first example of depicting AI's ability in uncertainty management.

Fig.4.1.1 The brief development history of AI

Source: Wei Yao, ResearchGate
https://www.researchgate.net/figure/The-brief-development-history-of-AI-AI-was-born-in-the-1950s-After-several-booms-and_fig3_344243595all-articles/xiongan-china-special-economic-zone/

Alan Turing introduced the famous Turing test, which is a way of testing a machine's intelligence. The artificial neural network was introduced.

"Artificial Intelligence" was first proposed in Dartmouth Conference by J. McCarthy. The golden years of AI began.

The first chatbot named ELIZA was created, but ELIZA communicated only by convention, not by true intelligence.

1950 1956 1966

Deep Blue, a computer program created by AI, beat world chess champion Garry Kasparov.

The rise of expert systems made AI flourish again. Reinforcement learning also emerged during this period.

The artificial neural network was used to analyze the stability of power systems.

1970

1997 1980s 1974

The deep learning renaissance began with the discovery of how to successfully train deep neural networks.

The first AI winter came out because of the limited computer capacity, commonsense knowledge, reasoning, Moravec's paradox, et cetera.

2006

2011 2016 2018 2020

Deep learning and big-data are on the rise.

AlphaGo, designed with AI, defeated Lee Sedol, a world champion of Go.

Turing Award was awarded to three pioneers in AI: Yoshua Bengio, Geoffrey Hinton, and Yann LeCun.

Deep learning has become the hottest direction in AI, and it is also widely applied in smart grids.
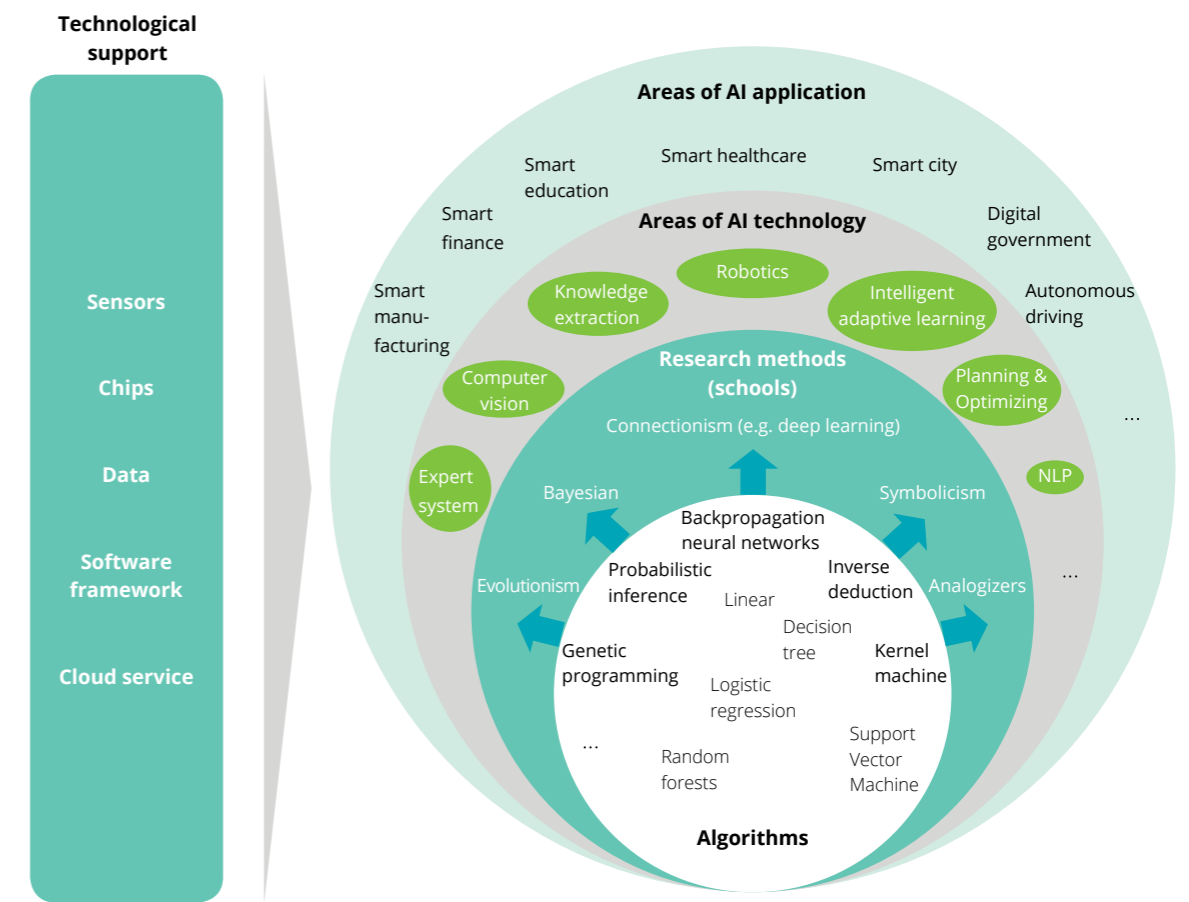
Fourth, having an ability to evaluate and to make decisions based on the harnessed information which might not be complete, then act rationally, is another indicator for intelligence. According to the AI scholars, referencing predefined performance measures and objectives which clarify what is right or wrong, acting in a rational way is trying to achieve the best results possible. Given to injure humans is wrong and this has been communicated to AI, its rationality is shown by avoiding hurting anyone in any possible scenarios.

Lastly, exercising the qualities and capabilities described above in an autonomous way, in other words, in an unsupervised manner which human beings are absent from the process or systems so cannot advise, remind and let alone to pose controls on any decisions made or actions taken. AI powered cars or robots which move around the city autonomous clearly demonstrate their final intelligent aspect.

People invest in Artificial intelligence with reasons, most of the time, those reasons or objectives can be classified into three categories based on the level of human intelligence they want to achieve inside a machine, namely, strong AI, weak AI and the in-between AI which takes a middle ground of them. Strong AI refers to the systems built that think exactly like humans do, genuinely trying to simulate human reasoning, those systems would possibly explain how humans think despite the real model is yet to be invented for now whereas the weak AI refers to the systems operating without understanding how human reasoning works which means the human thought is irrelevant to the computation, those systems focus on how well they can act and work like a human. The system of a master chess player developed by IBM's Deep Blue is an example of the weak AI. As the name suggests, in-between AI shares the qualities of both strong and weak AI, founding on the human reasoning to inform and inspire yet imitation is not the goal. The machine-learning systems that Amazon has been stressed and focused on can be seen as an in-between example. Learning layers of representations for tasks based on the data, those systems show the ability of pattern recognition and learning inspired by the human brain but not a real brain itself.

To conclude, by combining artificial and intelligence, an artifact can perform the discussed intelligent qualities in three classified degrees.

Fig.4.1.2 Illustration of all levels of AI

Source: Deloitte Research
https://www2.deloitte.com/content/dam/
Deloitte/cn/Documents/technology-media-te-
lecommunications/deloitte-cn-tmt-ai-report-
en-190927.pdf

4.2 AI In Architectural Design

Artificial Intelligence (AI), besides offering possible solutions to the limitations of parametric architecture, would radically open a new door for architecture in parallel to other practices. Welcoming to a new era of architecture to embrace: a statistical approach.

Unlike coding in which the designers or engineers set a series of rules, numbers or variables, a deterministic model is not built in the world of AI. Either collected from the data or transmitted by the users, AI allows the computer to crunch the data then to create intermediary parameters from the information in hands. The machine can generate solutions to answer a set of predefined constraints or parameters and to create results when its learning phase is achieved. The statistical distribution of the data collected or information received during the learning phase guides or inspires the AI system to propose those results. Results originated from the data, plus imitated the mathematical pattern, such innovative ideas are at the core of the paradigm shift thanks to AI.

Parametricism took the architecture world by storm in its debut, largely because it successfully introduced architecture to a completely new methodology. Instead of drawing the concepts and ideas like in the past, architects code them. Rationalizing each task into a set of simple rules which constitutes a procedure encoded in the program, thus, to automate an execution that was done previously in a manual and tedious way. Generating various possible scenarios, such as with different shapes, materials, options... (Fig.4.2.1) Instantly can be done at ease by architects, simply by changing the parameters. In short, parametricism is killing two birds with one stone solution as it lets architects master highly sophisticated shapes at the same time keep away from repetitive tasks.

The Generative Adversarial Network (GAN) is believed to be especially relevant for architectural design. Ian Goodfellow, a researcher at Google Brain, theorised GAN in 2014 with the first empirical demonstration of such an inventive approach. To describe architecture succinctly involves a generator model which takes input points from a latent space and generates an image together with a discriminator model which classifies images as either real (from the dataset) or fake (output by the generator). (Brownlee, 2019)

The invention of AI nearly disrupts all the premises of Parametricism, resulting in another novel solution to be adopted. Considering AI can digest a complex set of examples, plus its partial independence of the machine building, it is possible to have its own interpretation of a situation or problem. People do not have to define every single rule and parameter explicitly beforehand as machines can learn from inputs, therefore, AI is absolutely a leap and a transformation. Revising the thinking process shifting from commands to statistics.

4.3 AI In Urban Design
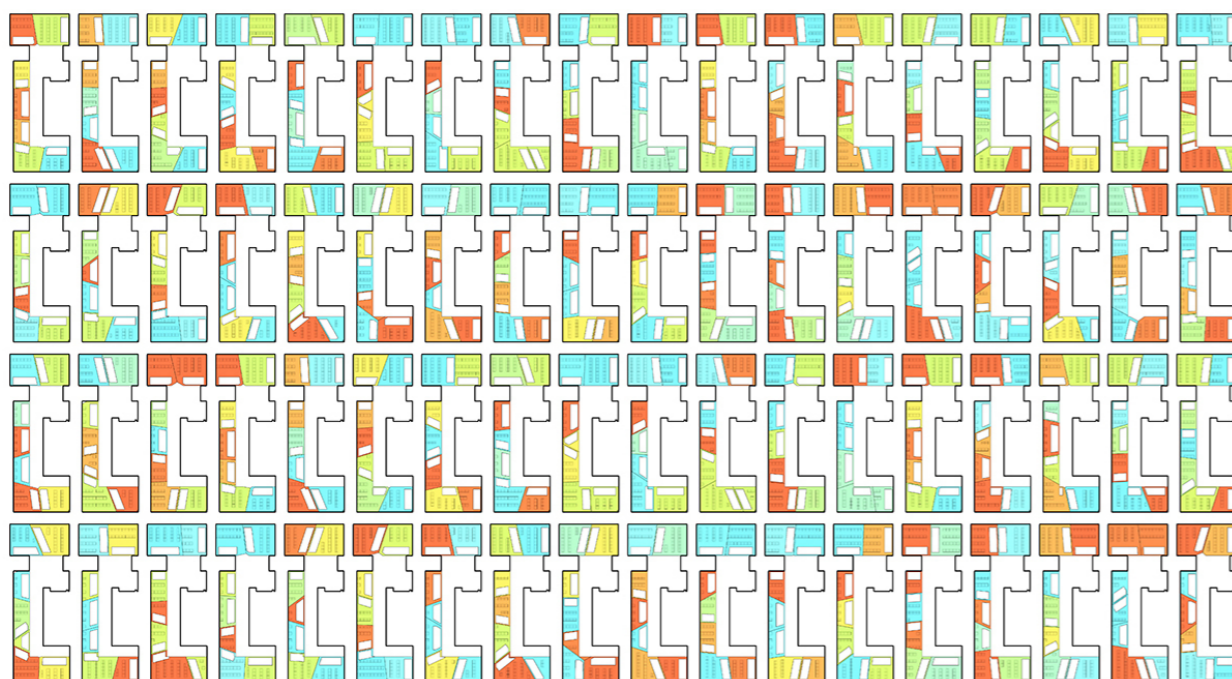
Towards participatory approach

Apart from having many extensive capacities, AI is famed for its extraordinary ability in managing and analyzing data which are incredibly preferable qualities for urban designers to make use of. Same as every single design on earth, if the goal is to design for the people, to understand people is the starting point to a successful design. When looking at a larger urban project, the number of requirements and obstructions bounding to the design can be easily multiplied. Moreover, globalization revised the structure of the city, resulting in a more diversified society, successfully magnifying the complexity a city can be. Facing all the complexities, especially the diversities among the urban population. Creating a desirable urban space has become more challenging in the past decades unless the likeness and the usage by the end users are irrelevant. However, if this is not the case, given they are both noteworthy attributes of a favourable urban space, designers have to make sure to pay enough attention to the people.

AI helps the designers to perform all the analytical tasks faster, more appreciably, it encourages public participation, for instance, by providing a platform for them to express themselves. By harnessing public views which are the data collected from the platform, designers comprehend better the attributes they have to incorporate into their solutions, ultimately to address their needs via design. CityScope is a data-driven interactive simulation tool for urban design, also a project conducted by MIT Media Lab's City Science Group. (Alonso. et al., 2018) Having the goal of improving urban design practices to facilitate consensus between stakeholders so they focus on the interaction of social, economic and physical characteristics of urban areas as their research topics in order to know how people experience and use cities.

Towards generative approach

A city's organization has never been simple, its complex structure with numerous layers interviewing to support its daily operations. Transportation, electricity, water, waste management...some layers might not be seen easily but they are crucial to build up a city. Whenever one of the elements is suspended, different degrees of inconvenience is anticipated depending on how important that service is to the concerned actors. All the factors and issues easily create a project which is full of problems and constraints needed to be solved. Therefore, architects or designers have to spend hours and hours on testing and refining designs to make sure the list of criteria is checked even before explaining to other parties.

Moreover, it is not astonishing at all that clients are likely to push so aggressively to shorten the design process, even most of the time architects and designs have to please them by proposing solutions within an extremely tight schedule, commenting on designs then re-proposing them, the process always goes back and forth till the greenlight is granted to the design, as a result, such process could be extremely lengthy and exhausting.

Spacemaker and Delve are generative design tools, using cloud computation and machine learning to propose optimal design solutions. AI enables the industry to revisit the waterfall of analysing, creating and evaluating an urban project. Undoubtedly, architects and designers are able to create even without AI, yet AI helps them to speed up the entire process, increase the transparency and cooperation between different stakeholders and ultimately achieve time and cost saving which become the main drive for more innovations and advancement of the technology.

Combined participatory and generative approach

Urban design is not a pure scientific profession, as the design part can barely be separated from art. The combination of art, science and humanity is inevitably pivotal to a successful and gratifying urban design project. Measuring scientific outcome or result can be done in a more objective way then evaluating artistic output as the latter relies heavily on preferences and likeness which are not always measurable and highly objective. Owing to this peculiar nature, under the same family of art, the design side of an urban project is also very much subjective. As a result, an urban design project is commonly divided into sub-area with heterogeneous characteristics, not only to divide the function, to increase its flexibility and to enlarge its targeted service groups which ensure the social diversification but also in a way building up the aesthetic diversification, be more appealing to a broader scope of audience.

As explained earlier, a city is evidently becoming more complex in many senses so do its demographic issues. Art has always been rooted deeply into culture, regarding their bonding relationships, it is not surprising to see more definitions of beauty growing in line with more diversified and thriving cultures.

The rapid development of AI further stretches its arm to dig into this aesthetic domain. Based on the data and information gathered, analysis and generative design solutions can be produced. A crowdsourcing effort called Place Pulse was launched around a decade ago, aiming at mapping which areas of a city are perceived as safer, livelier, wealthier, more active, beautiful and friendly. Asked people to rate the geotagged images photographed by them online then turning their answers into crunchable data. It became the pioneer to measure the aesthetic capital of the public which is eminently unthinkable and impractical before technological breakthrough. Another initiative called FaceLift is a combination of participatory and generative approach. (Fig. 4.3.1)

To encourage public participation by offering an open platform for expressing opinion, such an active approach to harvest data and then analyze them with AI can help architects, designers and other relevant parties to better address the humanistic side of an urban project more accurately and timely. For opinions that are normally hard to be interpreted let alone to collect them at ease like the aesthetic capital, researchers have tried to explore the applications of AI in those areas since they are aware of the importance of those intangible capital.

To conclude, this approach of combining participation and deep-learning generation fosters more interactions between different actors, solutions which might not be apparent at first to designers would still be generated and proposed by the machine if they are feasible and fulfilling the criteria listed. Incorporating aesthetic capital with the help of AI into an urban project reduces not preferable surprises to the designers also to the neighbourhood and end-users but enhances its acceptability and likability.

The potentiality of AI has been recognized and explored in the field of architecture and urban design. Its applications are getting wider and wider as researchers have been digging into AI's ability in offering a quality space, cityscape as well as citylife. Two real case studies taken from an urban Chinese context are used to illustrate how AI is being applied in various aspects in the next two chapters.

Fig.4.3.1 An illustration of the FaceLift framework.

Source: The Royal Society Publishing
https://royalsocietypublishing.org/doi/10.1098/rsos.190987
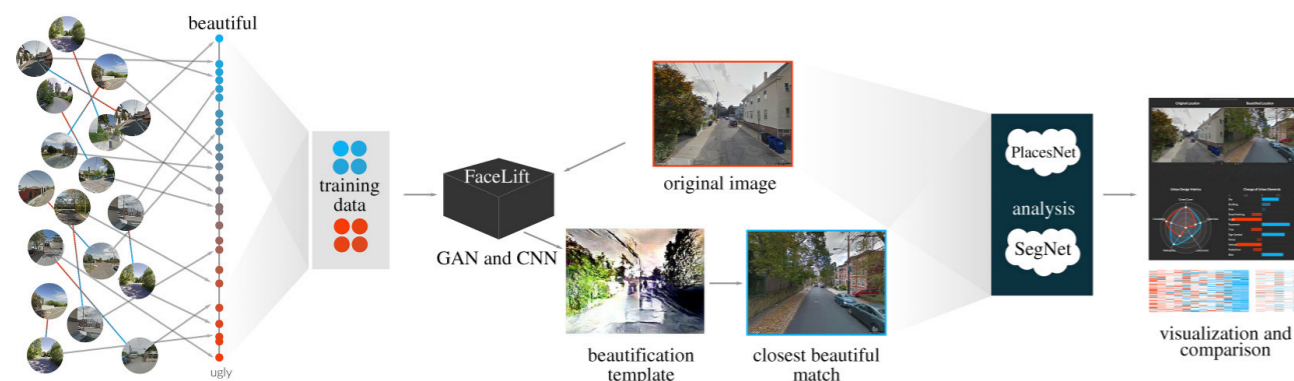
CASE STUDY - THE BRAIN OF A CITY

After introducing some crucial backgrounds related to smart city and AI, in this chapter, the focus is on understanding how AI is being applied to smart cities. The idea of Smart City was presented as a national strategy in China. To understand the role of the Internet in nation management and society governance profoundly is a must. Implementation of e-government and building new smart cities have become indispensable to national direction ever since then. By using examples, particularly a real Chinese example called City Brain is adopted to characterize their roles, more importantly, to show how and what the Chinese government has done with the aid from AI to integrate big data and to promote technology convergence, business integration and data convergence to achieve collaborative management and services across geographies, systems, departments and services. Ultimately, to see will and how the changes would affect architects and urban designers.

5.1 Made In Hangzhou

The number of AI corporations has been mushrooming in China with the government and capital support. In some cities, this phenomenon is obvious, such as in Beijing, Shanghai, Shenzhen and Hangzhou. Listed on the Nasdaq, Beijing Duoke Information Technology Limited (36Kr) published The overall AI development index among Chinese cities in 2020, these cities are also at the top ranking of the chart, taking the first to the forth places accordingly*. This index takes the environment for city development, financial support, research and development ability, infrastructural support and development results into consideration, thus analyzing the overall AI development in a city.

Hangzhou is the capital of Zhejiang province, according to the Hangzhou Statistical Bureau, it housed over 10 million people in 2019, yet the population is still the smallest among those top cities, approximately half of the population of Beijing and Shanghai. Owing to its scenic landscape with a famous lake and canals, it is named as the "Back-garden" of Shanghai. However, nowadays, Hangzhou is more than its natural beauty.

* https://www.huaweicloud.com/articles/9cfa-8ce7df41bacd239c495c66000d61.html

A presentation given by Wang Jian about Hangzhou City Brain

Wang Jian, chairman of the Alibaba Group Technology Committee, pointed out that the most important resource of a city today should be data and "city brain" will become the city's infrastructure.
Source: Alibaba
https://www.alibabanews.com/wangjian-chen-gshidanao-jiangchengweichengshidejichushe-shi/

400
350 368
300
250
200 185
150 131
100 95
50 39 25 16 12 10 9 6 6 5 5 3 1 1 1 1 1 1 1
0

Beijing Guangdong Shanghai Zhejiang Jiangsu Sichuan Fujian Hubei Tianjin Anhui Liaoning Shandong Henan Shanxi Chongqing Guizhou Tibet Hong Kong Guangxi Hunan Heilongjiang Shanxi

Fig.5.1.1 Distribution map of China's AI companies

Source: iyiou.com, Deloitte Research
Deloitte. (2019) Scenarios and Potentials
of AI's Commercial Application in China.
Deloitte.

The central government has already addressed its strategic orientation towards technology for many years. Hangzhou is one of the earliest cities in China which believes in the golden opportunities of developing technology and follows closely to the state's direction. Its local government has worked hard throughout the years to make the city more appealing; its determination and eagerness have been clearly reflected on its favorable policies and support to the development. Since 2016, many policies have been announced and put into action to support AI development across different stages, from incubation, acceleration to diversification (Fig.5.1.2). In the proposal published by the regional Zhejiang government in 2017, it stresses on accelerating the research of AI thus enhancing its in-depth application to further digitalize the regional economy for upcoming years. (People's Government of Zhejiang Province. 2017)

Made in China 2025	2015.5	Develop intelligent equipment, intelligent products and intelligent production
13th Five-Year Plan for Economic and Social Development of the People's Republic of China	2016.3	Include AI development into the 13th Five-Year Plan
Robot Industry Development Planning (2016-2020)	2016.4	By 2020, increase the output of self-developed industrial robots to 100,000 units, among them, over 50,000 have 6 or more axles
13th Five-Year Plan for National Technological Innovation	2016.7	Focus on developing big data-driven quasi-AI technologies
Special Campaign on Advancing Innovative Development of Intelligent Hardware Industry (2016-2018)	2016.9	Prioritize the research of wearable devices, intelligent on-board equipment, intelligent healthcare equipment, intelligent service robots, industrial grade intelligent hardware equipment etc.
13th Five-Year Plan on Developing Emerging Sectors of Strategic Importance	2017.3	Come up with the concept of AI 2.0; include AI into national strategies; mention AI into government work report for the first time
Notice on New Generation of Artificial Intelligence Development Plan	2017.7	Establish a new education system that include intelligent learning and interactive learning; promote the application of AI technologies in teaching, management and resource construction; promote AI courses in elementary and secondary schools; higher institutions encourage more students to pursue "AI+x" master/doctor's degrees; and build more intelligent and interactive education platforms
19th CPC Congress report	2017.10	Include AI into the report to promote deep integration of Internet, big data and AI with the real economy
Three-Year Action Plan on Promoting the Development of New Generation AI Industry (2018-2020)	2017.12	To refine and implement tasks outline in the plan; focus on the industrialization and integrated application of new generation AI technologies; and promote deep integration of AI and the real economy
2.0 Action Plan on Promoting IT-based Education	2018.4	Energetically advance intelligent education, create student-centered intelligent teaching environment, promote the application of AI technologies in teaching and management, expedite the reform of talent cultivation model and teaching method with AI technologies, and explore ubiquitous, flexible and intelligent teaching environment and application models
Modernization of Chinese Education Industry 2035	2019.1	Innovate education service formats, co-construct and share digital education resource mechanism, improve interest allocation mechanism, IPR protection system and new education service regulation rules. Drive the reform of education governance approaches, accelerate to build modernized education management and monitoring system, and realize precise management and scientific decision-making.

Fig.5.1.2 China's National AI development policies

Source: Deloitte Research
Deloitte. (2019) Scenarios and Potentials
of AI's Commercial Application in China.
Deloitte.

AI Town is an important project created and implemented by the Hangzhou government to encourage AI development. Hangzhou Future City dedicates approximately 100 square meters to house this special town, focusing on developing infrastructures, software and digital platforms for AI, a specialized industrial cluster for AI is then formed under this government supported initiative. Thanks to such a strong strategic focus, more than 420 AI companies have been settled there. The strong technical foundations built up inside the AI Town have created favourable conditions for pushing them to the application level and ultimately reaching the market and being ready for the public. The applications of their AI research or business are vast, ranging from smart household, smart security, smart manufacturing to smart medicine and so on. Hangzhou High Technology Industrial Area is another example alongside this AI Town which aims at providing an area for gathering and encouraging talents to immerse themselves in contributing to the AI industry.

Hangzhou is a second-tier city but a well-developed one has already been appealing to many creative classes. Unlike Beijing, Shanghai and Shenzhen, the price tags of these first-tier cities can be scary to a lot of them. Its housing and cost of living are comparatively more affordable so it has already successfully attracted talents to come. On top of that, the local government has further emphasised on this comparative advantage by generously giving out monetary rewards, first, to catch their eyes then attract and retain them to stay. For both projects mentioned above, AI Town and Hangzhou High Technology Industrial Area, attractive monetary policies, such as tax reduction, direct subsidy and remuneration have been offered to eligible parties.

The Hangzhou government takes an active and leading role in turning Hangzhou into a smart city, aggressively developing its smart economy by pushing technological advancement. AI is obviously part of the plan. Over millions and millions* have been invested into the AI industry and its supporting activities. These governmental supports have created the ripple effects, successfully triggering the involvement of the public. Some non-government initiatives driven by other parties are not rare but getting more attention in contributing to the overall technological development.

All the commendatory factors found in Hangzhou have contributed to a preferable condition to start and run an AI project or business. As a result, according to the latest figures, there are 166 AI firms operating in Hangzhou which the majority have been established in the past five years (Yan, 2019). From 2015 to 2018, it shows the deepest increment. In short, these start-ups are growing rapidly and are thirsty for creativity and talents.

Besides attracting the talents to base in Hangzhou, the local government has invested in incubating its own talents and some private initiatives have also contributed to it. The major incubators are the Zhejiang University and Alibaba, in general, their research and development laboratories are divided into academic and business streams. For the academic oriented laboratories, the development can be traced back to the early 1980s whereas the business-oriented laboratories are developed more recently starting from the 2017.

With all the wills and actions to boost its technological role in China, Hangzhou has actively engaged in AI development, having a strong belief and vision in the data era. It applied over thousands of AI patents which ranked after Beijing in applying patents. Among those applications, Alibaba takes up the majority and ranks in the top 10 regarding volumes on a global scale (Yan, 2019). Hangzhou's willingness and ability have made her gain more attention and prominence overtime, not being restricted in China but going beyond.

(RMB100 million)
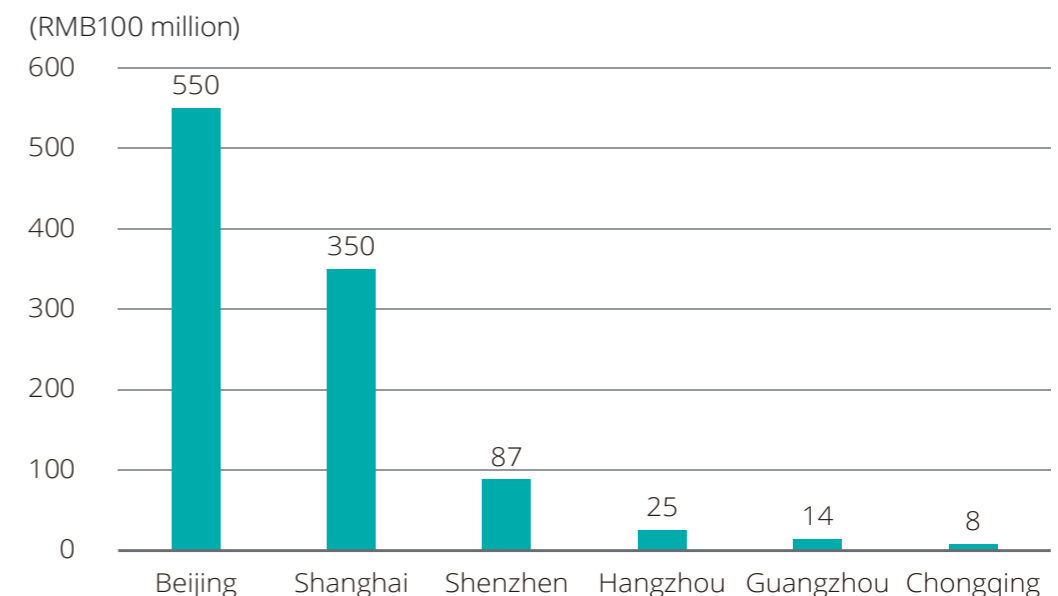
Fig.5.1.3 Number of patents held by reserach insitutions, universities and leading companies (by city)

Source: Deloitte Research
Deloitte. (2019) Scenarios and Potentials of AI's Commercial Application in China. Deloitte.

5.2 City Brain

In 2015, The Smart City Development Research Centre under The State Information Center (Administration Center of China E-government Network) published the concept of "Smart Heart Smart Brain" in a government paper. This concept focuses on collecting city's big data then applying AI and other technologies to construct a model to foster cross-departments or even cross-cities collaboration for city's management. Inspired by this ground-breaking idea, Wang Jian, the chief technology officer of Alibaba, announced its City Brain concept on behalf of Alibaba a year after during the 18th Donghu International Exposition, co-organised by Hangzhou Government and Alibaba Group. Built on heterogeneous and massive data, City Brain is a novel infrastructure adopting AI, cloud computing and IoT to solve urban issues which can barely be solved by the human brain. It can be seen as an integrated big data and AI solution for Smart City. An overarching program including a suite of acquisition, integration and analysis of enormous data generated on a daily basis is offered by it. Video and image recognition, data mining and machine learning technology are the diverse tools used to harness data in a complex urban setting. Working closely with the Hangzhou local government, they jointly release the City Brain concept and implement it on a real city scale in the same year. Their initial goal is to solve the problems resulting from the urbanization process in Hangzhou. Over the years, the technology has been evolving and so does City Brain. Beginning with the City Brain version 1.0 in 2017, in 2020, it has already been upgraded to the version 3.0.

Without a standardized definition of this concept, the City Brain idea has been interpreted by many researchers, focusing on its different aspects. Yet to Alibaba, City Brain is described and seen as a management system, adopting it to manage a city in a digital way. Using a cloud-computing platform developed by Alibaba and AI with other top-notch interdisciplinary capabilities integrated, City Brain can conduct real-time processing and intelligent computing with all the data collected from multiple sources described, thanks to it, the city's valuable resources can be managed and provide solutions to urban problems.

5.3 How Does The Brain Function

City Brain is one of the largest public artificial intelligence systems worldwide*. It operates in a logical workflow**, data is the preliminary step to kick start the flow. Data is generated and accumulated anytime and anywhere, no matter voluntarily or involuntarily, they are useless and worthless until they are collected in numerous ways for the following steps.

After harnessing data, Cognition follows. It refers to the ability of recognition, for instance, it can distinguish between people and cars, identify traffic status as well as accidents in the urban environment.

Decision and Optimization is essential at step three as to make decisions or optimize solutions used for operating a city referencing the cognitive results, automatic accident alert is an example for this step.

The fourth step is Search and Mining and it aims at building up a database and index by inserting everything the cameras have captured so searching through the data is possible. To discover the patterns found in data which help to know the cause of some urban issues, such as traffic jams.

Both current and historical data is stored which facilitates the next step: Prediction. It does not matter if it is in the short term or long term if it can predict what will happen in the future. Predicting if traffic congestion is about to happen within an hour or the possibility of having accidents within a few days because of the bad weather conditions are some common scenarios.

Lastly, with information and analysis resulting from the prediction, intervention can be made which is the ultimate step of the workflow as well as its goal to make constructive changes. Predicted results provide signals and bases to respond to situations by coming up with solutions beforehand, more importantly, getting prepared. For instance, patterns show bad weather is very likely to cause accidents on the road or city-wide events causing huge crowds which having traffic conjunction is highly probable, in these cases, traffic lights and other traffic devices can be adjusted to minimize the risk of causing urban turbulence.

Fig.5.2.1 The logo of Hangzhou City Brain

Source: Zhihu.com
https://zhuanlan.zhihu.com/p/92922996

In a technical point of view, City Brain functions in a highly systematic way with several hierarchies. The foundation layer is a unified computing platform, collecting both dynamic and static data from numerous sources and sensors, not only from the public bodies, like its city police and traffic police but also from the private internet companies. With a huge influx of data, the City Brain can start its calculation. The next level is a data resources platform, mainly dealing with the data security issue, to improve the quality of the data. Another level upward is the AI service platform, with all the advanced computations to support AI's deep learning ability, thus, to dig out all the useful information which allow City Brain to think and to analyze. The top level is the IT service platform, providing the ability to notice the urban accident or incident rapidly, even instantly, thus, to manage them quickly without serious delay causing huge disruption or worse, urban catastrophe. This level can also foster the industrial ecosystem to flourish.

To conclude, in either perspective, City Brain is structured sophisticatedly which allows it to perform its tasks methodically.

Fig.5.3.1 The Architecture of City Brain
Source: Alibaba
https://uploads-ssl.webflow.com/5b20fdf-071061967d188a98e/5bb693e27653212e-ce95077d_Alibaba%20Cloud%20ET%20City%20Brain_28.09.2018%20Riga.pdf

5.4 What Has The Brain Done

City Brain covers a wide variety of services, security, tourism, agriculture... Some critical services are discussed and divided into four main categories related to social management and public security, traffic congestion and traffic light control, public transportation management and lastly urban sensitivity and digital solution.

Social Management and Public Security

City Brain provides a single platform for the municipal government to manage Hangzhou and all the described application systems contribute significantly to social management and public security. Its outstanding capability of analysing visual images and videos helps the government to streamline a lot of traditional workflows to re-allocate its human resources. Since these systems have been in force in the city, not only pickpocketing and other petit theft can easily be spotted by it, criminal offenses and urban fire can also be recognised. Moreover, when an accident happens, it helps the police or other related parties, such as firefighters and medical officers, to visualise and understand the seriousness without even being onsite which significantly improves the efficiency and collaborations between them. As a result, allocating resources to cope with unexpected events has become more effective.
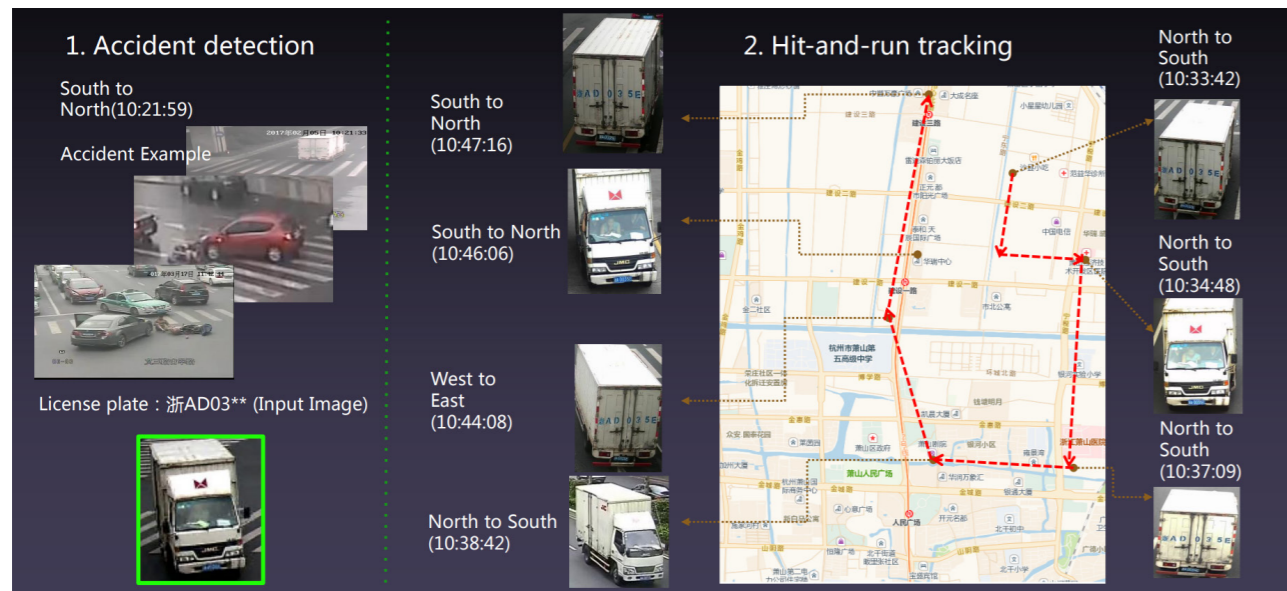

Fig.5.4.1 The Dashboard of City Brain
Source: Bloomberg
https://www.scmp.com/tech/enterprises/article/2114965/alibaba-says-it-track-overtake-amazon-worlds-top-cloud-computing City%20Brain_28.09.2018%20Riga.pdf

Traffic Congestion and Traffic Light Control

City Brain collects data coming from all possible sources, such as Google, traffic police and surveillance videos, with all this data, the traffic condition no matter on highways or roads can be evaluated and analysed which can reveal the reasons causing congestion and again accidents can be easily recognised by it. AI can be understood as the main supporter behind the traffic light control system, with its deep learning ability, it learns from the data to analyze the traffic condition thus to adjust the traffic light system accordingly. Through such constant analysis, traffic lights can perform at an optimal situation without a fixed duration but a dynamic adjustment. Covered over 1,000 crossroads, connecting to approximately 4500 control sensors. Such a traffic management system enabled by City Brain lessening the traffic congestion problem at the same time improving the efficiency of some urban operations in an exceptional way. Sensors connected to City Brain are also installed in special vehicles running over the city, like ambulances and firefighting trucks, allowing them to arrive at their destination with time shortening near to 50% and during the way, only green lights are shown. These adjustments sometimes might be too trivial to be noticed let alone be seen by citizens but they contribute remarkably to solve the traffic congestion problem which has been bothering Hangzhou city.

Public Transportation Management

City Brain aims at improving the overall efficiency of public transportation. It can sense the density of the crowd of people based on the data collected. These collected data can also allow the system to analysis and to project the potential influx and outflux of people, consequently, they guide the design of the transportation system, for instance, where to put bus stops, how to organise and reorganise the bus routes, how to adjust the operation time of buses and so on. Apart from the buses, this data can also be useful to the taxi drivers who can understand the fluxes of people. Furthermore, parking can be a real headache to many people and can also be taken care of by City Brain. It knows how many cars are inside the city together with how many parking lots. Notifying the number of parking lots which are available, on the other hand, not available. Other information, such as turnover rate of the parking, adding all the pieces of clues together allow City Brain to generate a wider picture of the issue and eventually provide predictions and advice for further intervention.

Urban Sensitivity and Digital Solution

City Brain can identify traffic accidents and traffic congestions (Fig.5.4.2). As the information and platform is shared among different government offices, when emergencies happen and spotted by it, it automatically sends signals and allocates resources to cope with the situation at once, for example, sending emergency vehicles to the affected area and adjusting traffic lights for them to arrive as soon as they can. According to the official data, there are 3,400 sensors to keep track of the traffic condition and there is a check every two minutes to capture nearly instant conditions (Sun et al. 2019). Over 110 types of accidents can be recognised by it, there are approximately 30,000 times of accidents reported by the sensors every day and its accuracy is over 95%. In short, the response to emergencies and accidents could not be as immediate as now with the help from City Brain.

Fig.5.4.2 Demostrating how does City Brain track detect accident and track down hit and run vehicle

5.5 City Brain And Smart City

* https://edition.cnn.com/2019/01/15/tech/alibaba-city-brain-hangzhou/index.html

Hangzhou was ranked the fifth most-congested city in China but has fallen to 57th since City Brain was launched*. Solving the traffic congestion problem was one of the very first goals of implementing City Brain in Hangzhou. However, obviously, its impacts have gone far beyond traffic issues, applications have kept improving and expanding, stretching over many different disciplines and areas. Referring to the Concept of Smart City Indicators proposed by Rudolf Giffinger, indicators including Smart Economy, Smart Environment, Smart Government, Smart Living, Smart Mobility and Smart People, City Brain truly enhances the smartness of each category despite degrees vary. Again, City Brain is not equivalent to a Smart City but Smart City can be smarter because of City Brain.

Smart Economy

City Brain stimulates the development of the Information Technology industry, not only bound to certain types of technology but in a wider sense because it always asks for more, more advanced technologies to improve the existing version, which explains clearly why City Brain has already been upgraded to the 3.0 version since its first launch in 2016. Besides the technology itself, businesses also benefit from the continuous development or even breakthrough in technology, to explore the practicality of applying technologies into their business model, thus to improve efficiency, effectiveness, profitability...or all. For instance, City Brain's operation system designed for the agricultural industry has pushed one of the most traditional industries in using AI for raising cattle or keeping bees**. Instead of relying on luck and the "grace of the sky" which most of the Chinese farmers hold a strong belief in, City Brain offers a supplementary solution to them to know the conditions of the crops and animals, to ensure or improve the quality of their products. Besides the production process, other functions, such as marketing and sales, have also been covered by the City Brain's application. More and more applications of City Brain are expected to be invented, seen and adopted.

** https://developer.aliyun.com/article/783296

Smart Environment

With City Brain, a future city will take up only 10% of existing usage of resources, including land, water and electricity. This is the vision of Wang and his plans to change the existing cities with technology. City Brain helps the city to allocate resources in a scientific way and saves a lot of energy. It is rather common to see fingers pointed to cities for their superfluous energy consumption, some are used and some are simply wasted. Undoubtedly, excessive energy consumption has already shown countless disastrous signals and worse consequences to us. City Brain can contribute to some environmental issues by again providing constant data to need parties to carry out different operations. Power station failure can be detected in an early stage, via alerting the system, electricity can be reallocated and eventually be saved. Reducing the overall seriousness of traffic congestion in Hangzhou is an indirect but obvious way to curtail the energy consumption from cars, moreover, it reduces toxic particles and other pollutants released by them. Similar examples like shortening commuting of vehicles thus optimizing energy consumptions are common thanks to City Brain. Its prediction ability can also contribute to a greener environment through forecasting the environmental quality with follow up actions. Water, noise and air pollution monitoring systems can monitor pollutants and pollution levels, then give out environmental warnings. All in all, different contributions made by City Brain to the environment can be summarised.

Smart Government

* http://theory.people.com.cn/BIG5/n1/2019/0908/c40531-31342597.html

There are around 52 government departments with 760 information systems within the Hangzhou municipality*. Before City Brain, the data generated from these 760 platforms were not connected within the department, let alone across those 52 departments. Isolation does not only result in low transparency but also inefficiencies, ineffectiveness or even waste and loss. Imagine all the administrative processes to go through before the implementation of City Brain. Now with a combined platform for all the government bodies and its database is available to any parties upon request, lots of tedious and non-value-added processes can be eliminated. Owing to this digital convenience and connectivity, inter-discipline collaboration has become merely a challenge. Furthermore, with all the data harnessed inside the city, city governors are aided in the analytical process by AI, to be informed about and understand everything happening and happening inside Hangzhou, its citizens, its environment, its security and so on and so forth. City Brain is a tool, to assist and to help them to manage the city in a smarter and more rational way depending heavily on data and behavioural facts.

Smart Living

Applications coming from City Brain make peoples' lives smarter in many senses as they cover many aspects of daily life (Fig.5.5.1). There are 37 scenarios with its applications and insights into municipal affairs, such as tourism, office park, medical care, education*... It is expected to further increase the number of applications. One of the conspicuous aspects shown in the smart medical services. It provides an information platform for health, data and information regarding personal health and records can be tracked from the platform with permission. Medical professionals can understand better about a patient's health condition and medical history which is particularly handy to elderly who can easily forget their medical history and those who have difficulties in describing their health condition or state of illness. With its medical application, payment after having medical consultation has become hassle-free which allows patients to pay digitally within 48 hours, long queues accompanied with frustrations have been replaced by lower waiting time and lower medical fees thanks to simplified administrative process. City Brain enables citizens to enjoy the convenience that it brings into their daily life.

Smart Mobility

City Brain systems achieve over 92% of recognition accuracy rate in video inspection**. A network of traffic lights to automate traffic control and management are connected to the systems. Thanks to City Brain, the transportation speed has increased by 15%. Real examples show that it takes 4.6 minutes less on average to travel 22 Km on the original heavily congested Zhonghe-Shangtang elevated highway. Identifying the fastest route for special vehicles to arrive at the scene within the shortest time frame so such route optimization for them has increased by 50%. Ambulances arrive at their destination 7 minutes faster on average***. All these measures explain the capabilities of City Brain in lessening the traffic issue in the urban scape. Its contribution can also be seen in parking. There are approximately 476,000 parking lots connected to City Brain so citizens can easily locate where to park, not only to reduce the time cost of the drivers but it also encourages them to park legally, not to block and cause traffic disputes on the road because of parking. Moreover, a mobile application offered by City Brain allows drivers to pay after parking which is applicable to over 30 thousand parkings in Hangzhou (Fig.5.5.2). Some of the usual practices and designs have been questioned by the technology thus pushing them to change, for instance, it is very common to have a bar blocking the car park entrance, however, more and more bars are taken down by the technology in Hangzhou as it offers an alternative to pay digitally without the necessity of building a barrier

gate. Now, only 2.6 seconds is needed to pass a pay station at any of these "new" pilot parking lots.

Smart People

It is rather common to have the illusion that elderly are not part of the technological movement, either being excluded or being reluctant, City Brain revises these perceptions by actions. They are not forgotten, it helps them with their exceptional analytical skills, in particular those living alone, when the electricity, natural gas and other utilities are running out in their households, signals are sent to the local officers automatically, such alert helps the elderly to get rid of the inconvenience and possible difficulties. More vulnerable groups in the society can be taken care of with more targeted strategies to foster an inclusive society. Education has always been one of the major pillars to incubate smart people, efforts put into this are never parsimonious but generous. Both public and private actors have continuously made a lot of remarkable contributions to research, education and training to ensure people are well-equipped to cope with any Smart changes in life.

Fig.5.5.1(Left) The Apps of Hangzhou City Brain - showing different city services

Source: Hangzhou Municipal
http://hangzhou.zjol.com.cn/jrsd/bwzg/201912/t20191231_11528179.shtml

Fig.5.5.2 (Right) Smart Parking by City Brain - Go and Pay

Source: Xiaoshan Net, Xiaoshan Daily
http://m.xsnet.cn/html/2020/lc_0827/56479.html

5.6 Export The Brain

Hangzhou Bureau of Data Resource was set up in 2017, a year after the City Brain was launched. Its relatively recent inauguration reveals the plan and ambition of local government, also its optimism in data, to establish a standardised approach in urban services by using data, eventually maximising the usage and value of data collected from City Brain or other digital platforms. Despite City Brain having been jointly rolled out by Alibaba and Hangzhou municipality, their roles in the project have never been the same. The former focus more on the technical know-how side whereas the latter roots themselves on the implications side, in other words, the municipality has never changed its role but only changed its tool in ruling and management. The AI-powered tool enhances them to execute their duties to cope with the ever-changing society.

As discussed, Hangzhou was selected as the first city to implement City Brain for reasons, yet it is not a utopian example which rests uniquely in Hangzhou, in contrast, it has served as a reference and prototype for other cities. Since 2016 till now, the concept of City Brain has been applied in other 22 Chinese cities, such as Beijing, Shanghai, Guangzhou, Macao, Haikou...as well as outside China, in Kuala Lumpur, Malaysia (Fig.5.6.2). Although they are all Asian cities which share similarities, obviously they are very different in many aspects. Even Hangzhou is very different from Macau and Hangzhou and Kuala Lumpur. A flexible implementation of City Brain in a distinct context is still feasible owing to its co-production network which is contingent on the specific context. Furthermore, its flexibility can also be shown in its applications, it is not fixed or rigid but subject to adjustments to meet the specific requirements. To put it in another way, it is a new tool to create a localised and customised suite of policies for city governors, to overcome standardization problems which do not fit to the context.

Just to imagine, human behavior is already diverse and it just got amplified in a hype-diverse society like today but this is what City Brain has been trained to work on. Again, the fuel for the City Brain engine Apsara is data, data to begin with has never been homogeneous but highly heterogeneous which elucidates its adaptation is not bounded by geographical concern but more on financial constraints, directions of governance and in some cases public acceptance. The foundation of City Brain is a massive and extensive network of digital infrastructure which is not affordable to every place on earth.

In certain aspects, it is true that the City Brain is not applicable for all and is bound by the intrinsic constraints of that specific context. Anand mentions

Hangzhou as an innovation hub and a relevant candidate under the classification of Type B: aspirational cities which can use mobile innovation and transformation within a short period of time due to unified institutions of government and the ability to deliver large projects (Anand, 2020). Viewing the capital required to build Hangzhou, also City Brain, it is not surprising to see this project can be seen as "a utopian product of hyper-globalisation of capital". City Brain is still a relatively new project, it has been improving. If this improvement can last, one day Hangzhou will become a Type A: pioneer city thanks to City Brain.

Fig.5.6.1 Distribution of cities where Alibaba Cloud ET City Brain have been implemented
Source: Alibaba
https://www.alibabacloud.com/blog/city-brain-now-in-23-cities-in-asia_595479

Fig.5.6.2 ET Brain will support Malaysia's digital transformation with cloud technology and AI
Source: Alibaba
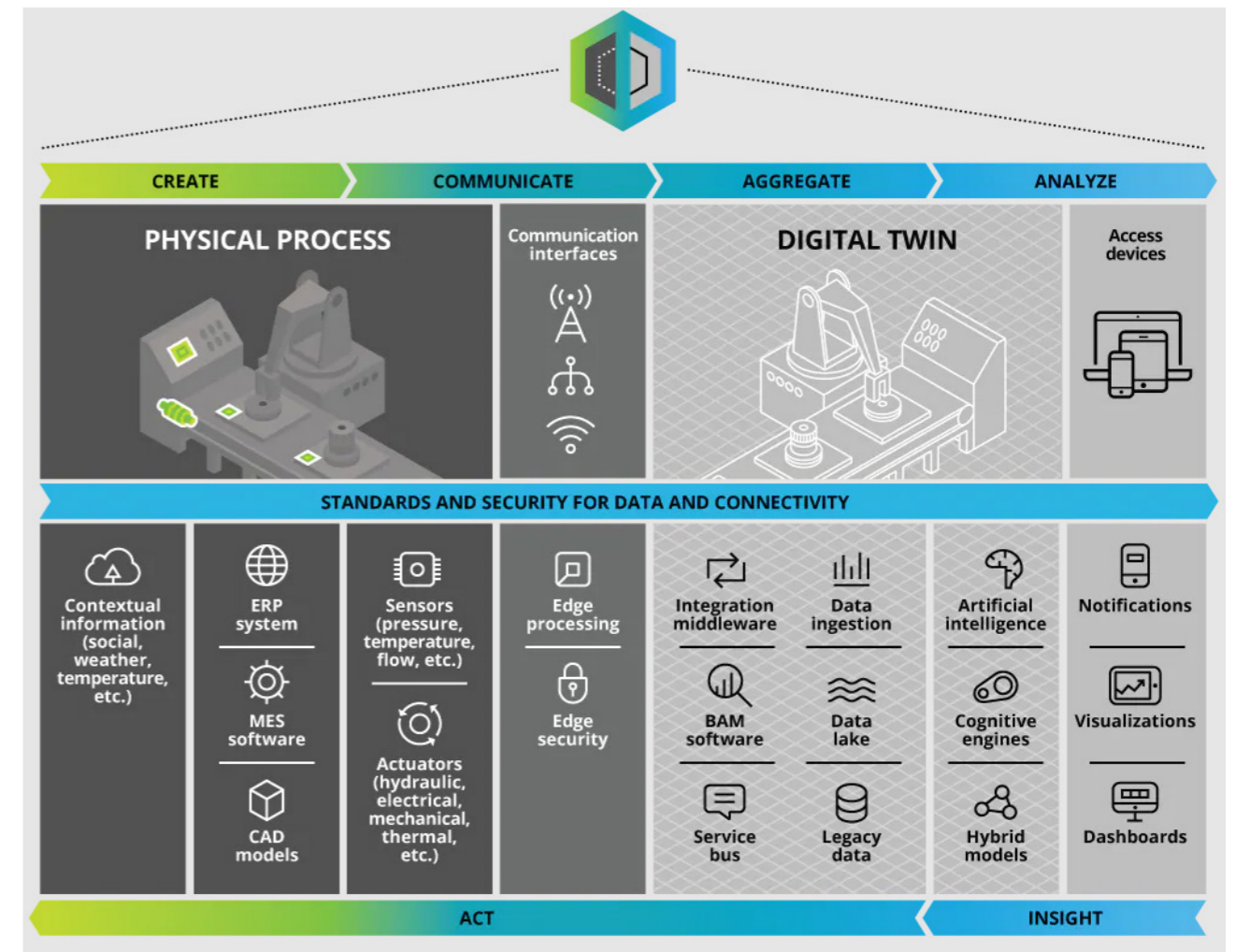http://stdaily.com/index/kejixinwen/2018-01/30/content_630977.shtml

5.7 From City Brain To Digital Twin Cities

City Brain has been widely used and quoted to manifest the success in strengthening the Smart City concept. Its achievements are undoubtedly apparent and evident in urban management which gives an illusion it is irrelevant to architects and designers, contrary, thanks to City Brain, Digital Twin Cities using AI have realized the Internet mode of data sharing, data co-creation and data automatic control and these are very relevant to architects and designers.
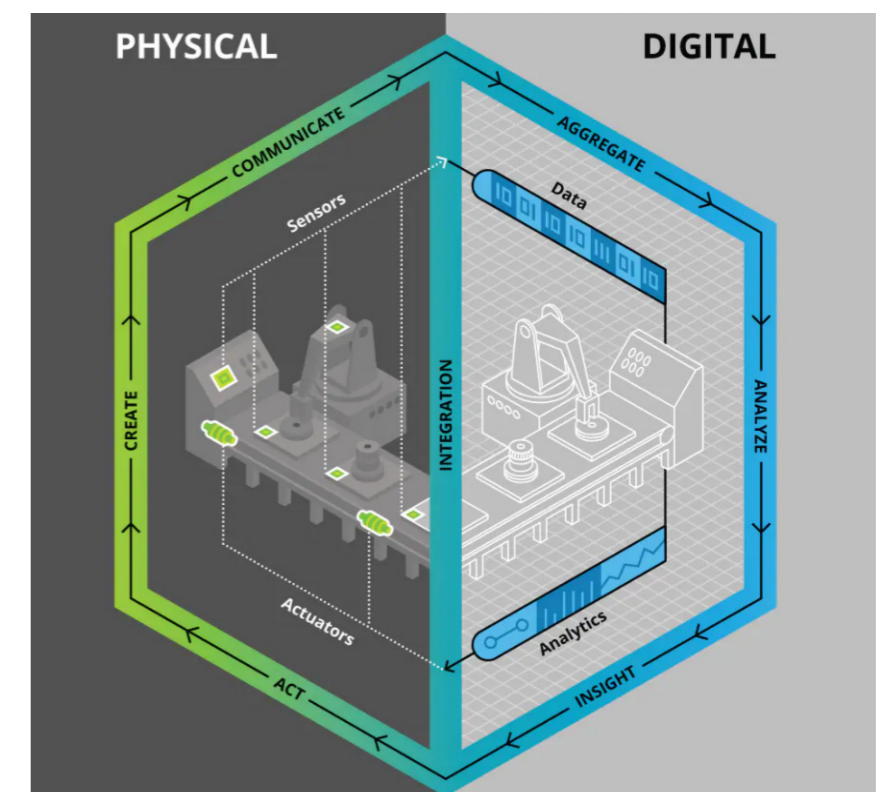
A Digital Twin is a digital model or replica of a physical asset, be it a product, an organisation, a public infrastructure or even an entire city (Fig.5.7.2). In the context of a smart city, a digital twin of the city continuously collects information from the built environment via technologies such as sensors, drones or mobile devices. It is made possible with the use of remote communication technologies such as Wi-Fi and Bluetooth as well as through IoT sensors that collect data from the physical world to reconstruct an identical digital copy of the city. Apart from IoT, the use of Big Data, Artificial Intelligence (AI), cloud computing, machine learning and advanced analytics also enhance the accuracy and dynamism of this replica, allowing static, historical and real time data to be processed and synthesised almost immediately to provide valuable insights about the performance of the city (PWC 2020).

This digital model marks the milestone of a data-based design approach. Data can be incorporated into two-dimensional digital images as well as three-dimensional models. This technology has already been applied into Building Information Modelling (BIM) which has gained popularity inside the industry, from design to build, from management to maintenance, from analysis to evaluation, it revolutionizes the industrial practice by significantly increasing the collaboration between different professionals. With City Brain and all its harnessed data, City Information Modelling (CIM) can be created at ease, BIM and CIM share similar logic but the application scale differs in which the latter is no longer restricted by scale and expanded. The possibility of combining both BIM and CIM results in a powerful tool for the industry.

Fig.5.7.1 Digital twin conceptual architecture

Source: Deloitte University Press
https://www2.deloitte.com/us/en/insights/focus/industry-4-0/digital-twin-technology-smart-factory.html

Fig.5.7.2 Manufacturing process digital twin model

Source: Deloitte University Press
https://www2.deloitte.com/us/en/insights/focus/industry-4-0/digital-twin-technology-smart-factory.html

Environmental data from the sky, ground, underground, water and underwater together with the behavioral data from the people. A city is a three-dimensional physical entity containing countless amounts of invisible data. Before implementing the concept of City Brain, data is not combined but scattered around, it is still possible to collect information separately and combine it manually but instant data cannot be reflected which means only static information can be shown but not the dynamic one so the analytical ability is hindered without the help from City Brain. With all the combined data harnessed from every concern of a city, a Digital Twin City as its name suggests, can mirror to a real city, a real city with multiple layers (e.g., buildings, transportation system, landscape, underground utilities…) that is digitally built with numbers becoming an important foundation for urban design.

Technological breakthrough has once again challenged the so-called normal practice inside the industry. It takes years or even decades for urban designers to see their outcome to be realised. In such a fast-paced era, everything can happen within a second. To put it in another way, when the designs are realised, they might already become obsolete to that current condition. Hence, it is afraid that such a long process can no longer be tolerated in the existing speed of urbanization. The new numerical methodology allows designers to create and simulate at the same time, helping them to obtain optimal solutions based on their goals and criteria, the accuracy of the render is escalated, both in terms of aesthetic and realistic representation.

In a nutshell, AI technology embedded inside City Brain gives new possibilities to architects and designers to image and to design a city, the new level of accuracy enables them to propose a more contextual solution which suits a city the most.

Fig.5.7.3 Dashboard of 51World Digital twin CIM system developed by Huawei

Source: Huawei

https://marketplace.huaweicloud.com/contents/ed66206b-3d7b-4be9-ba07-bff6e17fbb61
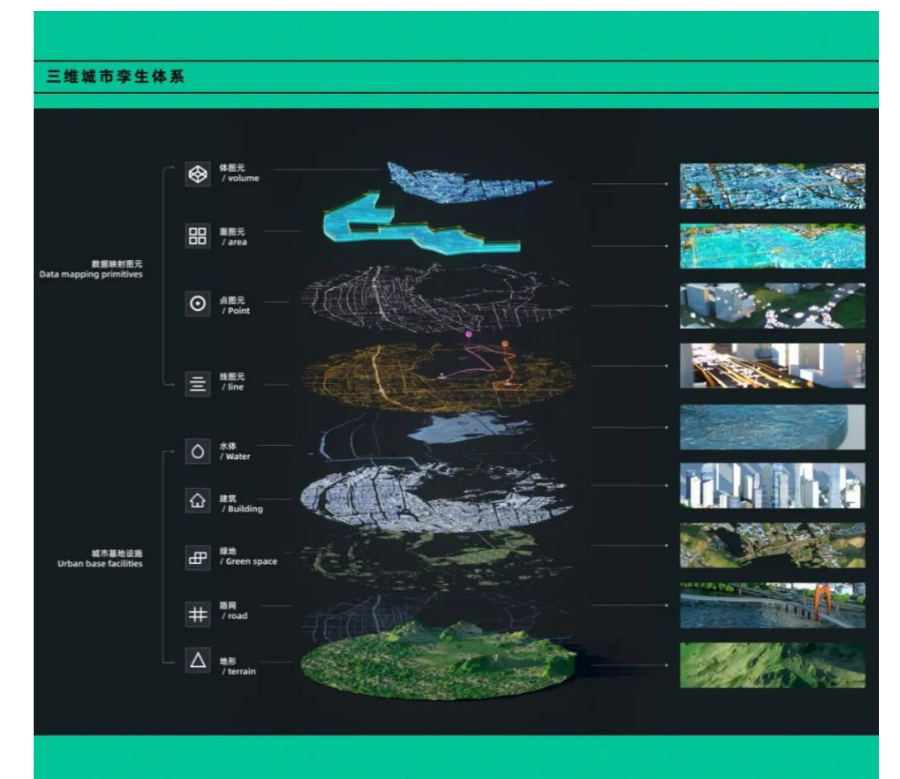
Fig.5.7.2 Explaniation of various layers applied in the digital twin city

Source: Alibaba

http://www.shejitk.com/archives/10533

CHAPTER 6|

CASE STUDY - A CITY OF NOW AND FUTURE

City Brain is explained in the last chapter, in the following chapter, another ambition project is elucidated - New area in Xiongan. This project is very different from the previous project. Hangzhou was already a well-developed city in China even before the implementation of City Brain but Xiongan is almost like a blank canvas. City Brain was introduced to Hangzhou city until the time was right and the technology was advanced enough to tackle problems found in the city whereas the latter, the project of Xiongan, called by the national press as the "Millennium Plan, Big National Affairs"*, his plan to build a city entirely from scratch. Even though some infrastructures have been completed, the construction of Xiongan city is still ongoing so AI can be adopted at the very beginning of the project and incorporated into this future city at any possible aspects, resulting it as an AI City narrated by many presses and is seen by many as the next stage of a smart city.

6.1 Made In Xiongan

On April 1, 2017, Xiongan New Area was formally established. This New Area features geological advantages with convenient location and easy to connect transportation system, an excellent ecological environment with ample resources and rooms for long term expansion.

Its total land area** is 1,560 km², among them, the arable land area occupies more than half of its total area which is 958 km² (e.g. accounting for 61.39%); urban and rural construction land takes up 310 km² (e.g. accounting for 19.91%); 194 km² of wetland with Baiyang Lake as the main body (e.g. accounting for 12.45%) and 98 km² of woodland (eg. accounting for 6.25%). These figures show the importance and dominance of the primary activities to the area before the strategic intervention of the State.

An urban design scheme for the first phase of development of Xiongan New Area proposed by Skidmore, Owings & Merill LLP (SOM) and Tom Leader Studio (TSL)

The Administrative Committee of Xiongan New Area selected proposal made by SOM & TLS for the first phase of development of a new economic zone, envisioned as a model "city of the future" for China.
Source: SOM & TLS
https://www.som.com/news/som_and_tls_selected_to_design_core_of_xiongan_new_area_chinas_model_city_of_the_future

Located on the North China Plain, in the east of Baoding City of Hebei Province, Xiongan New Area is composed of Xiong County, Rong Cheng County, An Xin County and some surrounding areas (Fig. 6.1.1). Its centre is about 130 kilometers away from Beijing Tiananmen and Tianjin's centre*, approximately 60 kilometers away from the new airport in Beijing: Beijing Daxing International Airport. Few years after the official announcement of its establishment, in fall 2020, The Beijing-Xiongan New Area Intercity Railway (Beijing-Xiong Intercity) was completed and in service (Fig. 6.1.6 & 7). This is the first opening of the new section from Beijing-Xiong Intercity Daxing Airport to Xiongan. From now on, within 50 minutes, the intercity railway can bring passengers directly from Beijing West Railway Station to Xiongan New Area, for those departing from Beijing Daxing Airport to the same destination, it will take only 20 minutes. Even though the highway is free from traffic, without Beijing-Xiong Intercity, it takes nearly 2 hours to drive for the same route**.

Xiongan's attractiveness is not only about transportation convenience which can be well-connected to the capital (Fig. 6.1.4 &5), some other major cities and critical infrastructures. Its low population density and low level of development with ample available spaces also reveal the potentiality of Xiongan; these conditions are positive for having a relatively long-term vision. Its latest registered population is composed of 45 minority groups. Record shows that Xiong Country's population is about 380 thousand, the population for Rong Cheng County and An Xin County are 390 thousands and 260 thousands respectively, the total population of 1 million people*** is spread over the total area around 1,560 km², resulting in a relatively low density (eg. 642 people / km²) comparing to Beijing (eg. 1,136 people / km²) and Tianjin (eg. 5,016 people / km²).

Owing to its strategic location, Xiongan New Area is selected to form a "one body, two wings"^ with Tongzhou and the "one body" is Beijing. The sub-center of Beijing, Tongzhou is adjacent to Guomao and Yanjiao, located in the east of Beijing.Its geographical significance lies in the relocation of the municipal government to Tongzhou, which will promote the development of the northern three counties and the entire east and north hinterland of Hebei. For Xiongan, it aims to promote the development of the southern part of Hebei and the northern part of China through relieving Beijing's non-capital functions and further promote the coordinated development of Beijing-Tianjin-Hebei, ultimately to reconstruct the urban structure of the North.

Xiongan New Area is China's 19th national-level new area and the first national-level new area to be established by the notice of the Central Committee of the Communist Party of China and the State Council. It is positioned as a second-class city and is the third new area* with national significance after the Shenzhen Special Economic Zone and Shanghai Pudong New Area.

The Shenzhen Special Economic Zone in the 1980s acted as a window and experimental field for opening and economic reform in China; it has strongly promoted the rise of the Pearl River Delta. Later in the 1990s, The Pudong New Area focused on comprehensive reforms and finance, driving the Yangtze River Delta to become the second pole of China's economy. As the third new area, The Xiongan New Area focuses on dissolving Beijing's non-capital functions, serving as the capital's sub-center, adjusting and optimizing the urban layout and spatial structure of Beijing-Tianjin-Hebei (ie Beijing, Tianjin and Hebei) and fostering a new engine for innovation-driven development. The state sees it as a would-be China's "Silicon Valley".
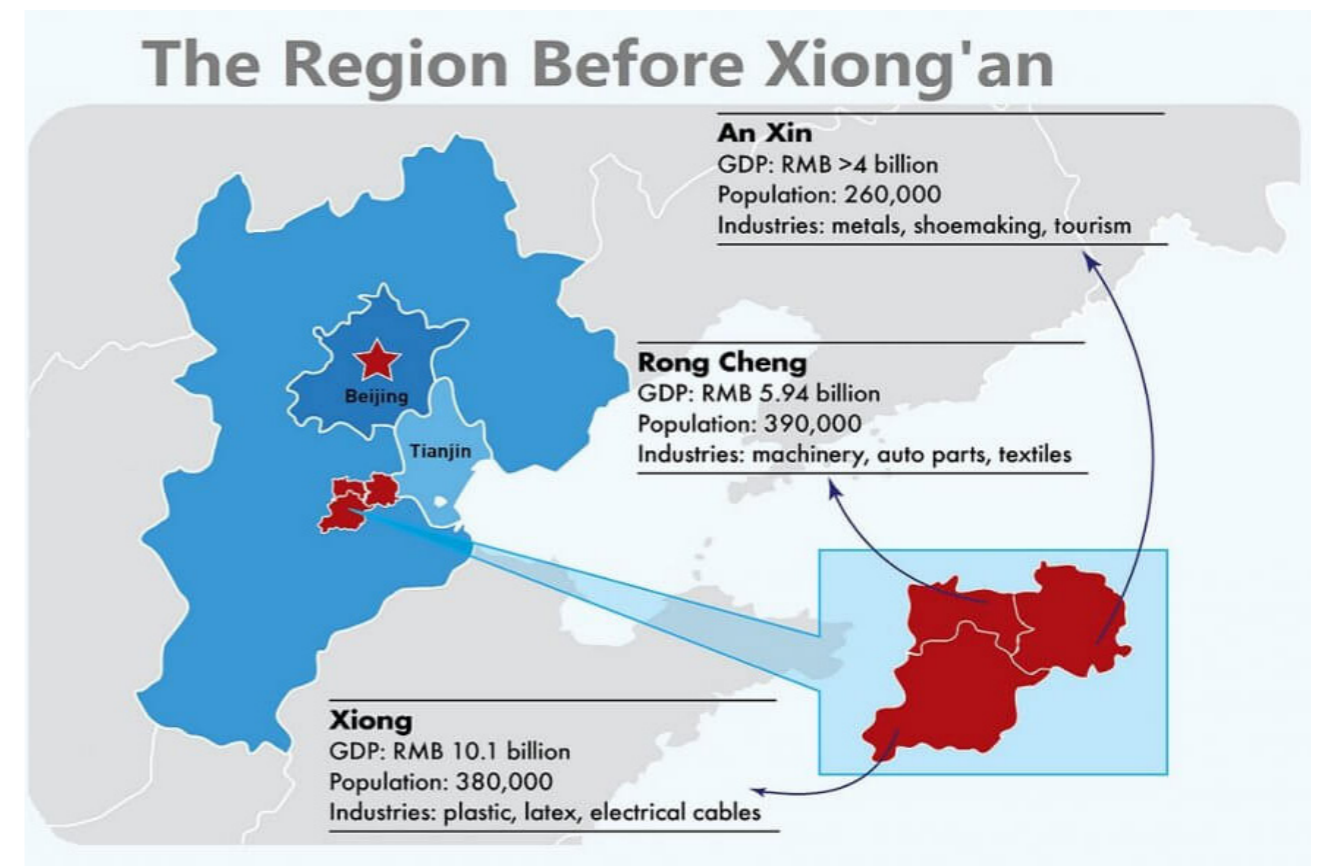
Fig.6.1.1 The region before Xiongan Xiongan New Area : China's Newest Special Economic Zone

Source: CKGSB KNOWLEDGE

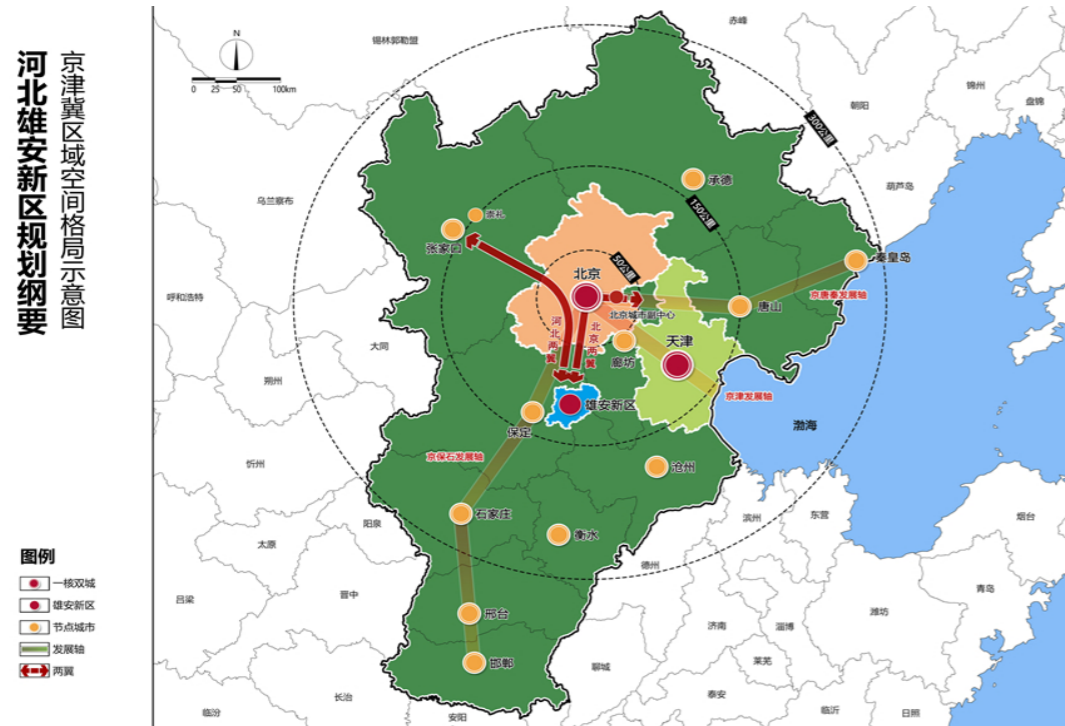https://knowledge.ckgsb.edu.cn/2017/11/08/all-articles/xiongan-china-special-econo-mic-zone/

Fig.6.1.2 Schematic diagram of the Beijing-Tianjin-Hebei regional spatial distribution

Source: Xinhua News Agency

http://www.xiongan.gov.cn/2018-04/25/c_129858651.htm

Fig.6.1.3 Schematic diagram of the space layout of the first phrase

Source: Xinhua News Agency

http://www.xiongan.gov.cn/2018-04/25/c_129858651.htm

Fig.6.1.4 Plan of regional rail transit planning

Source: Xinhua News Agency

http://www.xiongan.gov.cn/2018-04/25/c_129858651.htm

Fig.6.1.5 Regional highway plan - "Four verticals and three horizontals" regional expressway network

Source: Xinhua News Agency

http://www.xiongan.gov.cn/2018-04/25/c_129858651.htm

Fig.6.1.6 Beijing-Xiongan high-speed railway marks new milestone

Source: Sun Lijun,China Daily
https://www.chinadailyhk.com/article/14032504/25/c_129858651.htm

Fig.6.1.7 Aerial photo shows Xiongan Railway Station of the Beijing-Xiongan intercity railway

Source: Xing Guangli, Xinhua News Agency
http://www.ecns.cn/hd/2021-04-01/detail-ihaixiqm7139120.shtml

6.2 Goals Of Xiongan

To lessen some existing problems that the Capital is facing, it is listed at the top priority for developing Xiongan. First, it helps to phrase out the non-capital functions from Beijing. Beijing is positioned as a political, cultural, international, scientific and technological innovation center. Related supporting activities cannot be removed completely but retained there. The focus to relieve the burden of the capital city is through relocating some tertiary industries such as regional logistics bases, some functions related to social public service such as education, medical, training institutions and some administrative and institutional service to the New Area by building up new branches or headquarters which do not affect the role of Beijing, in contrary, Xiongan has to support and strengthen it.

Xiongan has to alleviate problems at the same time to explore opportunities. Seen as a pioneer in reform and innovation and these are the qualities at the same time requisite of the citywide project. The project is activated with a clear mind of changing the development pattern of the entire Beijing-Tianjin-Hebei region and exploring the future development path of China. The core concept of reform and innovation here is expressed in terms of five goals complementing each other*:

First, to establish a new image through three main aspects, city life, ecology and humanity. Constructing a vibrant city so people are willing to come and stay by connecting it to the high-speed railway network and highway network, improving its overall external connectivity, by enhancing the function of its water area and water network, improving its infrastructure for essential utilities, by building iconic pieces of architecture and districts, by pushing the construction of smart city...all these are examples of creating a new city image. The ecological image to be created in relation to water, greenery and scenic views whereas for the humanistic image to be formed by positive attitudes, such as inclusivity and diligence.

Second, to build new functions. Not only having a complementary role to Beijing but also constructing its own path, aiming at relieving some of the capital's functions on the one hand, developing new functions for a prosperous economy and emphasizing on the people-centric features on the other hand. To boost the economy, to promote innovative development vigorously by developing high-tech industries, to promote smart development by building digital ecosystems for production services, business models, application scenarios and financial services and to promote open development. Providing adequate public service and facilities and empowering the digital elements in urban management and construction are part of the plan oriented towards its citizens.

Third, to develop new industries. Offering a favourable environment which is appealing to both investors and entrepreneurs, to encourage them to invest and form industrial clusters, building industrial ecology and industrial image rapidly. IoT, softwares, services for IT, application scenarios and digital economy are the five key industries that are targeted and to be developed strenuously, to strive for turning Xiongan New Area as a demonstration zone representing the digital economy. Modern life science and biotechnology industry, new material industry and green ecological agriculture are other named industries to be focused on. The duo roles of Xiongan again have to be emphasized by exploring the co-operation model with the capital: headquarters or operation centers in Beijing, subsidiary or innovation center in Xiongan. Combining traditional industry relocation and regional collaboration, exploring the possibilities of achieving an Enclave economy.

Fourth, to gather new talents. Setting up Xiongan as a special zone for getting both national and international high-tech talents and experts together. Strategies to captivate talents from all over the world are at top priority, in pursuit of forming a pool of genius gradually. To foster knowledge exchange across regions by implementing exchange plans designed for cadres in the New Area and developed regions such as Beijing-Tianjin, the Yangtze River Delta and the Pearl River Delta. High-level young talents are welcome to the new area for innovation and entrepreneurship. Extra efforts are put to cultivate new talents by creating efficient training program systems and accelerating the training. A group of outstanding young cadres thus to be trained and well-prepared for the development. Making Xiongan a city to settle down by increasing their protection by helping them to secure housing and optimising the enrollment policy for their children. All these gestures showed that the government believes talents are inevitable to the success of the development, no matter, short-term or long-term, generous resources are earmarked for grooming, attracting and retaining them.

Firth, to build a new mechanism. The role of reform and opening as the fundamental driving force for developing Xiongan New Area has been revealed through releasing administrative resources fully with comprehensive improvement of work and service efficiency. To innovate new investment and financing mechanisms by exploring new and alternative ways of investment and financing, by striving for support from direct financing, by attracting social capital to participate in the construction, by setting up the Xiongan Equity Exchange...all these plans are oriented towards creating a pioneering zone for financial innovation. Furthermore, to explore new mechanisms for urban development in accordance with the principle of moderate scale. Ultimately, to endeavour a market-oriented development model that integrates investment, financing, development, construction and operation.

These five New objectives set for Xiongan New Area give a clear direction for its ongoing and upcoming development.
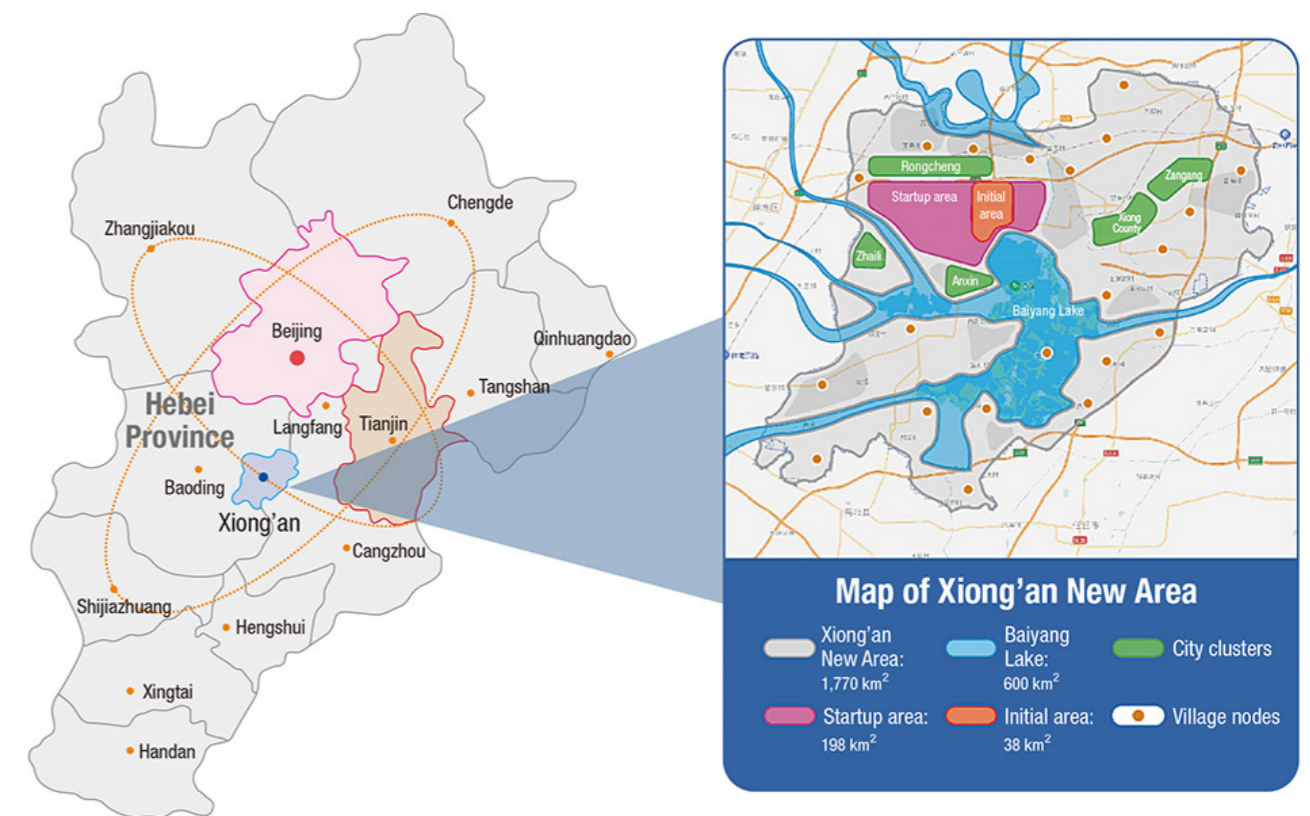
Fig.6.2.1 Map of Xiong'an New Area and Overview of Development

Source: HCR&D
https://www.hitachi.com/rev/archive/2021/r2021_01/gir/index.html

6.3 City Of The Future

^https://news.cgtn.com/news/2021-04-01/ Chart-of-the-day-The-rise-of-a-future-city-Xiongan-New-Area-Z6wXpqPJwA/index. html

Xiongan is undergoing a rapid transformation to share the burdens of the strained capital and strive to become a top-notch, sustainable and smart city by itself. The Future City covers an area of 1,770 km² and spans over three counties in northern China's Hebei Province^. The initial development zone occupies 198 km² with 100 km² designed as the planned construction area. Among them, an area of 38 km² is designated as Pilot area where construction starts first and that serves as an area for the city's innovation model (Fig. 6.3.1).

* https://www.globaltimes.cn/content/1044380.shtml

The project for the future city commences at 100 km², passing to 200 km² before reaching the 200 km² in the long term. In the same month after announcing the establishment of the Xiongan New Area officially, Hebei Province invited international bids to plan and design for this project*. International companies are welcomed to bid with their ideas for a 30 km² area at the initial stage.

* http://www.xinhuanet.com//english/2017-04/01/c_136177270.htm

President called for efforts to build Xiongan as "A demonstration area for innovative development" which shows his strong faith in new technologies, believing it will bring far-reaching changes to urban development*. In planning and designing of Xiongan, the application and integration of the IoT technologies, AI, big data and cloud computing are resolutely encouraged. Xiongan was selected as a platform and a city for new technologies to thrive. Unlike other renowned smart cities in China which are approaching a more mature stage of development, Xiongan is completely fresh and ready to embrace all kinds of advanced technologies. Intelligent infrastructures with smart sensors and lighting and facial recognition systems are some basic features of the future city.

** https://www.globaltimes.cn/content/1081294.shtml

To develop the Xiongan New Area, the roles of technology companies cannot be underestimated, let alone overlooked. Some leading giants have had cooperation agreements with the local government. On November 8 and 23, 2017, Alibaba and Tencent signed strategic agreements with Xiongan New Area respectively and on December 20, in the same year, Baidu also signed a strategic cooperation agreement with Xiongan New Area Administrative Committee**, hoping to make this project a new benchmark of AI city. Baidu President, Robin Li said that Baidu aims to assist Xiongan construct AI infrastructure and become a world-class smart transportation city with efficient transport. Some technologies have already been tested by them there, such as autonomous driving vehicles equipped with its Apollo platform. Expected that AI technology to be adopted extensively to solve the problems of traffic congestion, identification and authorization, green economic development and public efficiency improvement in the New Area.

*** http://news.cyol.com/content/2019-03/31/content_17973880.htm

Since the official launch of the project in 2017 (Fig. 6.3.3), relevant departments have convened more than a thousand national and international experts and more than two thousand professional technical personnel to establish a number of planning, evaluation and verification institutions, including a working group for Xiongan planning, a planning consultation experts group, national-level advisory and verification institutions and a provincial government experts committee***.
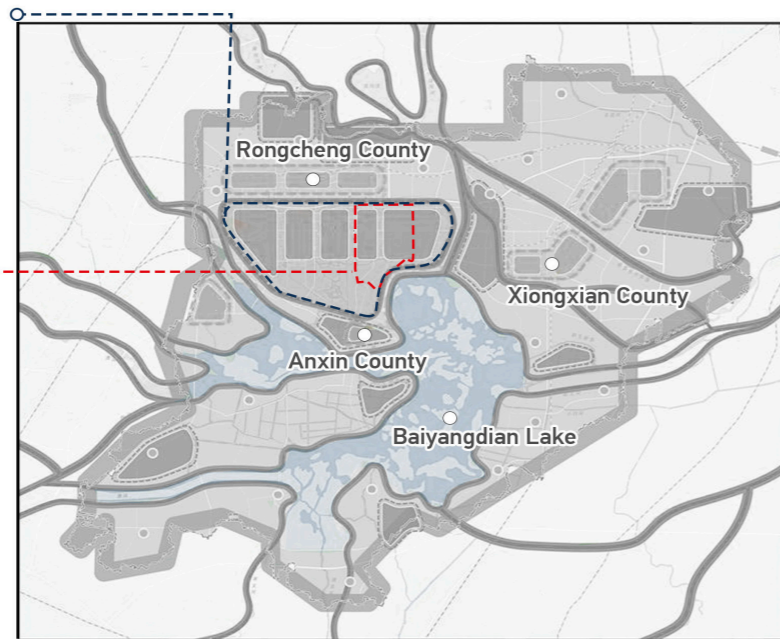
Initial development zone
Area: 198 km²
Planned construction area:
100 km²
Road network density:
10-15 km/km²

Pilot area
Area: 38 km²
Planned construction
area: 26 km²

Urban park area per
capita > 20m²
Urban green coverage
rate > 50%
90% Green commuting
100% Clean heating

Fig.6.3.1 Schematic diagram of the Xiongan New Area layout

Source: CKGSB KNOWLEDGE
https://news.cgtn.com/news/2021-04-01/ Chart-of-the-day-The-rise-of-a-future-city-Xiongan-New-Area-Z6wXpqPJwA/index. html

In 2021, infrastructure construction and the implementation of major projects have been pushed forward. Over 120 projects of public service facilities, infrastructure and ecology are underway. Some buildings have recently been capped, such as the basement of the third bid section of the Xiongan Business Service Centre with about 900,000 m² construction area and more than 800 resettlement buildings in the Rongdong District and Rongcheng County*. Yet, some have just planned for commencement of construction, like the internet industrial park, a science and technology park, a research institute and a digital trading centre. Besides these constructions, to strengthen the protection for the New Area environment and enhance the local Baiyangdian Lake's water quality have also been put on the agenda.

According to the official releases, the infrastructure in the initial development zone will be basically completed and the prototype of the urban area will begin to appear in 2022**. Then 13 years after, in 2035, a high-level modern socialist city which is harmonious between man and nature, with green and low-carbon, openness and innovation, information intelligence, living and employment, strong competitiveness and influences will be built.
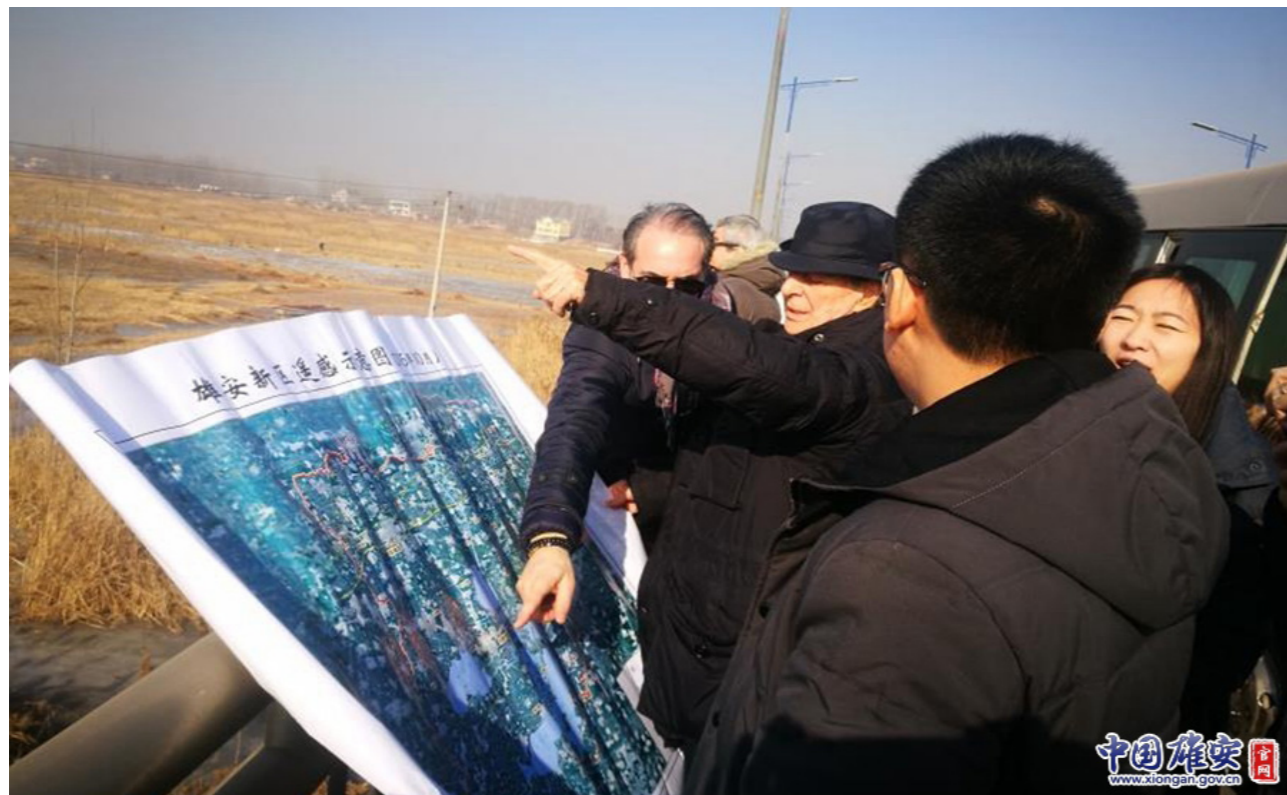
Fig.6.3.2 The planning team conducts on-site inspections

Source: Xiongan New District Planning Research Center
http://www.xinhuanet.com/2019-04/03/c_1124322416.htm

Fig.6.3.3 (top) Milestones of Xiongan New Area since 2017

Source: CGTN
https://news.cgtn.com/news/2021-04-01/Chart-of-the-day-The-rise-of-a-future-city-Xiongan-New-Area-Z6wXpqPJwA/index.html

Fig.6.3.4 (bottom) Citizen Service Center of Xiongan New Area

Source: Yang Shiyao, Xinhua News Agency
http://big5.www.gov.cn/gate/big5/www.gov.cn/xinwen/2019-01/02/content_5354281.htm#1
html

April 1, 2017
Establishment of the Xiongan New Areas is announced

December 7, 2017
Construction of the Xiongan citizen service center begins

February 28, 2018
Construction of the Beijing-Xiongan Intercity Railway starts

May 1, 2018
Xiongan citizen service center is put into use

December 25, 2018
Chinese central authorities approve the 2018-2035 master plan for Xiong New Area

February 1, 2019
A water conservancy project that diverts water from the Yellow River to yangdian Lake is put into operation

August 30, 2019
China (Hebei) Pilot Free Trade Zone is launched, covering four areas inclu Xiongan Area

December 2019
Two plans for the construction of a starting area in Xiongan New Area ar approved

March 2020
Construction of a green horticultural park starts

March 31, 2020
A blockchain lab is established in Xiongan New Area

December 27, 2020
The Beijing-Xiongan Intercity Railway is put into operation

6.4 Xiongan New Area And Smart City

Without having many constraints posed by the existing condition, Xiongan New Area is a new canvas for imagination and experiments. Rather than allocating most of the resources to tackle the current problems, much effort is spent on anticipating the future, trying to learn from the past experiences and other cities and avoid the mistakes that were made before. Based on the Smart City Indicators proposed by Rudolf Giffinger, indicators including Smart Economy, Smart Environment, Smart Government, Smart Living, Smart Mobility and Smart People, are used to understand how Xiongan New Area will become a smart city step by step.

Smart Economy

The central government has emphasized the importance of using technology and particularly data to fuel its economy. In Xiongan New Area, not surprisingly, to develop its own Smart economy beside supporting the Capital city is one of the key items found on its strategic plan. Wu Hequan, Beijing-Tianjin-Hebei Cooperative Development Expert Advisory Committee Vice Deputy head, says It can be predicted that high-tech industries will be the engine of China's economy in the future and this is also the mainstay of Xiongan. In the future, Xiongan, 70% to 80% of the economic contribution will come from high-tech industries (Wan., Yu. & Qi. 2018). As mentioned, many technological giants have signed up strategic agreements with the government and set up offices in the New Area to support a massive construction of its Smart economy. Besides, many high technology focus companies have registered its business there (娱乐经典. 2018), carrying out pilot projects for the innovative development of trading services, supporting the establishment of comprehensive cross-border e-commerce pilot zones and building a global-oriented digital trading platform are some measures leading to a high-technological development and a strong and vital economic system for the New Area. Incentives and priority are given to the high-technology firms to create a focused direction for its economic development, added that rather than continuing their business as usual as in other cities, they are encouraged by the government to concentrate their business on working on new projects and researching on new technology. To establish a clear role of Xiongan within a bigger scope of the high-technology industry.

Some physical spaces are dedicated to support and foster this Smart economic development, for instance, China Zhugezhuang Industrial Park, Cross-border E-commerce Comprehensive Pilot Zone, was opened in December 2020 *. Aiming at creating an industrial ecological service system oriented towards digital

trading and an industrial cluster which appeals to talents and digital economic enterprises. An extensive range of services, including but not limited to product design, digital marketing, international logistics, supply chain finance, smart customs clearance and so on are provided in the Park.

Smart Environment

Utility is a significant topic in creating a smart environment as it has a close relationship with energy. Looking at the past and present, both the quality and quantity of energy consumed and provided affect the environment. Owing to its importance, it is also a topic that has been taken extra care of in constructing Xiongan New Area and undoubtedly the traditional way of providing and managing utility services have been further digitised and intelligentized, expected that smartness can contribute to the greater concern of sustainability.

The digital active power distribution network to be adopted in Xiongan New Area will apply means of intelligent perception into power transmission, transformation and distribution, to realize information exchange and sharing. Counting on technology such as advanced intelligent IoT sensing and big data analysis, power supply companies can fully provide user services online, to track and meet users' demands more accurately. Level of accuracy can help optimising the usage, in other words to reduce wastage.

Users can inquire about electricity consumption at any time and adjust their behaviours regarding electricity consumption to save energy and cut their bills based on the data analysis*. Compared to the current practice, the power grid monitors used by the power supply company can only monitor the distribution network, information regarding the electricity consumption of a household cannot be understood, nor can it provide users with better services in the future. Moreover, since distributed power sources such as photovoltaic power generation and wind power generation are getting more connected to large power grids, people can choose "whether to sell electricity and when to sell electricity" according to the distributed power generation situation so as to obtain better users' experiences and possibly economic benefits.

Besides measures designed for an individual's or household's level, other Smart environmental measures* can be found in a boarder environmental level, for instance, its environmental monitoring system, an automatic environmental monitoring superstation that integrates air quality automatic monitoring, water quality automatic monitoring, weather automatic observation, hydrological automatic monitoring, water pollution automatic traceability, and 5G video monitoring together with unmanned monitoring ships and drones, forming an all-rounded environmental monitoring system.

Smart Government

A first unmanned police station was debuted in 2020 on Rong Cheng Jintai Road in the New Area (Fig. 6.4.1 & 2). Some self-service equipment is installed to serve its citizens, like replacing ID cards, handling illegal traffic, endorsing entry and exit documents...rather than going through all the processes done by a policeman, these machines can do these tasks autonomously and cut the waiting time as people are not required to wait there in person to secure an appointment but to make a reservation based on their availabilities. These machines do not only provide convenience and efficient service to the citizens, at the same time, they free up some police force to be re-allocated into other aspects.

Technologies provide alternative ways to the police to govern a city and to the city governors to manage a city. Hangzhou's City Brain project is discussed extensively in the last chapter. In Xiongan New Area, a similar concept is implemented**. Although its smart city operational system is not operated by the same technological company, its brain can function for its own needs respecting its own situation. Carrying out tasks that crossing profession, department or region thanks to real-time data processing and data fusion application innovation, government affairs, security, transportation, medical, logistics and other fields of application systems to be grow on a same digital foundation, same logic is built up and come out from the same brain which minimise the coordination problems no matter in terms of people or information in and for governing.

Moreover, dynamic face recognition, continuous real-time tracking and automatic target discovery at long-distance are some functions to assist the city governors in overlooking the entire city more efficiently and effectively supported by data, AI and other deep learning analysis.

Fig.6.4.1 The exterior of the Unmanned Police Station in Xiongan New Area on Rong Cheng Aowei Road

Source: Xiongan Government
http://www.xiongan.gov.cn/2020-01/20/c_1210446885.htmmic-zone/

Fig.6.4.2 The interior of the Unmanned Police Station in Xiongan New Area on Rong Cheng Aowei Road

Source: Xiongan Government
http://www.xiongan.gov.cn/2020-01/20/c_1210446885.htm

Smart Living

Digitalisation has already been seamlessly incorporated into many daily aspects in China, Xiongan New Area is not an exception but pushing it into a new level, to explore more possible ways to increase the quality of life of all citizens regardless of age groups and demographics. Unmanned supermarket using behaviour capture and facial recognition technologies to shorten the checkout time (Fig. 6.4.4), smart hotel using smart front desk machine with face recognition and self-certification system*, these functions shorten the identification process thus check in time, unmanned vending vehicles, delivery robots and so on are some technological supported and transformed services to facilitate a smart living.

Work has also been done to improve social and digital inclusion, digital payment has widely been accepted and used across China, however, for those who do not possess a digital device, it hinders them from making a purchase online or even offline, being excluded from enjoying such convenience. Among all, the elderly or the underprivileged groups easily fall into this exclusion.

An innovative breakthrough can be seen in the New Area regarding this, a new exploration of digital RMB was made by issuing a corresponding hardware wallet**(Fig. 6.4.3). The advantage of it is that it has real currency properties, to store the encrypted currency as the digital renminbi in it. When receiving, exchanging or paying, it carries out the corresponding action to the other party's wallet just like cash, moreover, the internet is not required for the transaction. It is expected to apply extensively, now, it has already been combined for making a payment for charging electric vehicles***. Once the charging is finished, the bill is automatically deducted from the hardware wallet without further action or any hassle.

Despite some buildings and infrastructures having already been completed, the entire Xiongan New Area is still being constructed, including the housing units, more applications related to Smart living are anticipated owing to a growing population.

* http://www.xiongan.gov.cn/2018-10/24/c_129978062.htm

** http://www.xiongan.gov.cn/2021-04/09/c_1211104213.htm

*** http://www.xiongan.gov.cn/2021-04/01/c_1211093949.htm

Fig.6.4.3 Digital RMB "hardware wallet"

Source: Du Yahui, Xiongan Government
http://www.xiongan.gov.cn/2021-04/09/c_1211104213.htm

Fig.6.4.4 Consumers pay with their faces in an unmanned supermarket in Xiongan New District

Source: Yin Gang, Xinhua News Agency
http://xinhua-rss.zhongguowangshi.com/0/-3478954167513100731/6671521.html

Smart Mobility

Building a digital and seamless transportation infrastructure network is a clear direction announced by the Hebei Provincial Government for Xiongan New Area*. In order to achieve this, it has to combine new infrastructure with traditional infrastructure which are upgraded and transformed. Constructing Smart highways, Smart ports and Smart waterways, advanced technology empower the infrastructural industry to improve its efficiency and safety, orienting towards a high-quality development. Besides these Smart infrastructure, Smart transportation systems with autonomous buses have widely been tested and to be used.

For Smart highways, to promote the construction of its pilot projects such as the Hebei section of the Jingxiong Expressway, the Hebei section of the Jingli Expressway, the Jingshi Section of the Beijing-Hong Kong-Macau Expressway, the Rongwu Expressway, and the Jingde Expressway to achieve quasi all-weather traffic, expressway dynamic control and truck distribution. Application scenarios such as precise lane management ,coordination between cars and roads... have been built as a model for Smart Mobility.

For Smart ports, to promote this type of construction in Tangshan Port, Qinhuangdao Port and Huanghua Port through carrying out automated transformation and intelligent upgrade of port facilities and equipment, using 5G, BeiDou and other technologies to promote pilot applications of automatic driving of trucks in ports for collection and distribution channels. Lastly, Hebei Coal Trading Network Industry advantages can be utilized to build an integrated, visual and intelligent port smart logistics service platform.

For Smart waterways, to improve the construction of Baiyangdian digital tourism transportation channel, additional equipment such as environmentally and friendly buoys, remote telemetering and remote-control navigation beacon lights... are explored to obtain new multi-functional but integrated navigation beacons for pilot applications.

According to the plan, 80% of Xiongan's citizens** will travel by public transportation in the future (Fig. 6.4.5). Through the digital transportation platform, passengers can make reservations for autonomous buses by using smart devices such as mobile phones to enter destinations and other relevant information. Passengers can hop on a bus after passing the facial recognition system, they will be transported to the destination based on the optimal travel plan generated by the bus.

Lastly, located in the Xiongan Zhihui Future Science and Technology Park,Xiongan Intelligent City Digital Transportation Lab is crucial in researching and exploring Smart mobility possibilities (Fig. 6.4.6). Research on high-precision timing technology, indoor and outdoor precise navigation and positioning technology, also vision and radar multi-sensing data fusion collaborative products serving the intelligent traffic management...ultimately putting these ideas into implementations.

Fig.6.4.5 Workers maintain driverless buses in Xiongan New District

Source: Xing Guangli, Xinhua News Agency
http://xinhua-rss.zhongguowangshi.com/0/-3478954167513100731/6671521.html

Fig.6.4.6 The Xiongan Digital Transportation Laboratory in the Science and Technology Park

Source: Han Bing, Chinanews.com
http://www.chinanews.com/sh/2021/04-29/9467401.shtml
mic-zone/

Smart People

Technologies have been transforming the way people interact with each other, it also happens in Xiongan New Area. In a Chinese society, it is rather common for the grandparents to take care of the grandchildren while their parents leave for work, a lot of time in urban areas where more job opportunities are provided, explaining why Chinese New Year becomes the precious moment for their reunion. The first Smart and Safe Countryside* monitoring platform was developed in Xiongan New Area in 2021. With functions like high-definition monitoring, remote viewing, photo taking and video recording, voice intercommunication, anomaly detection, infrared night vision and so on, this platform is useful for providing care for care homes, remote cares for elderly and online cares for left-behind children. Thanks to this platform, migrant workers who cannot return to their hometown can talk to their parents remotely. Even if the parents do not have a smartphone, they can see each other and talk in the video every day or supervise their children's study and their life at home remotely.

Furthermore, smart development is emphasised in Xiongan New Area and talents are the foundation of it. Lots of effort has been made to foster talent developments and education to build up or enrich the labour competitiveness in the market. Laboratory for AI education in Xiongan New Area was established at Xiong County Baiyangdian Senior Middle School (Fig. 6.4.7). Built by Baidu Education**, Beijing Normal University Smart Learning Research Institute and Baiyangdian High School jointly, since 2018, it has provided integrated smart education solution regarding of AI, robotics, big data, IoT, AI experience area, AR experience area, brain science and other emerging technologies, to create a collection of curriculum resources, teaching platforms, hardware teaching aids, training projects and online experiences, to assist Xiongan New Area in AI and new technology innovation talents cultivation.

Fig.6.4.7 The Artificial Intelligence education laboratory of Baiyangdian Senior Middle School in Xiongan New District

Source: Wang Jun, Rmxiongan.com
http://www.xiongan.gov.cn/2018-11/09/c_129990365.htm

6.5 What Has AI Done For The Futrue City

Create a city of digital intelligence. It is necessary to adhere to the simultaneous planning and construction of digital cities and real cities, to appropriately advance the deployment of intelligent infrastructure, to build broadband, integrated, safe and ubiquitous communication networks and intelligent multi-source perception systems, to create a smart city information management hub. Ensure the security of smart infrastructure, smart hubs and applications in an all-round and full process, and build an urban network security assurance system. Establish a smart city operation model and smart governance system, improve the city's smart people's livelihood service system and build a world-leading digital smart city with deep learning capabilities. (The State Council. 2018)

Digital Twin literally refers to the digital copying of the entities in our world. As early as in 1970*, NASA proposed this concept which was to simulate spacecraft in outer space on earth to avoid accidents or disasters on spacecraft. Considering that the Digital Twin is a set of virtual information, to comprehensively describe the real or potential material world, in other words, any information used to build the real material can be obtained from the digital twin. It is another innovative topic of Xiongan New Area. The chief urban planner from China Academy of Urban Planning and Design comments on the role of the new generation of information technology in cities is shifting from digital presentation to intelligent experience (Du., Meng. & Chai. 2019). With the help of in-depth big data mining technology, AI, IoT technology and Internet platforms, future cities will undergo changes in the following dimensions of planning content, decision-making mechanisms, construction standards, and design models. Through an integrated cloud-network of three dimensional integration system, massive amounts of data are gathered and processed, connected and integrated on the data platform, linked and evolved with the help of intelligent engines, finally, intelligence will be applied to various fields of production, livelihood and various fields of social governance in Xiongan New Area.

The construction of Digital Twin City is one of the top priorities of Xiongan New Area development, it has also nurtured the new needs of future cities. Three key aspects are summarised for this move, according to Executive Deputy Director of the Future Laboratory of China Academy of Urban Planning and Design, Yang Tao : The first is the construction of digital intelligent infrastructure which will support the future digital development of the entire city. The second is the construction of an all-rounded smart environment so in reality the public space or indoor space is full of ubiquitous intelligent sensors and services, supporting the intelligent interface of having friendly interaction between man and machine. The third is to finally realize the concepts of digital asset trading, digital asset management and digital economic innovation proposed by the central government which will serve as a new driving force for urbanization in the future. It is anticipated that new urban forms will be derived in the future (Yang, 2020).

AI and other technologies are adopted together in different stages to realise Xiongan New Area, from planning and design, construction and supervision to management, some aspects are summarised and discussed in the followings:

Fig.6.5.1 The planning and design display of Xiongan BIM management platform

Source: Qianjiang Evening News
https://rss1.thehour.cn/news24/zaker/article/416592

Using AI to review design proposals

Following a logical life cycle of a city, Xiongan New Area's BIM platform is developed based on six management levels (Fig. 6.5.1) : planning, detailed planning, design, construction - supervision, completion - acceptance and operation - monitoring, with digital and technological support. It is composed of six BIMs : BIM0 (existing space), BIM1 (master plan), BIM2 (detailed planning), BIM3 (design proposal), BIM4 (construction supervision) and BIM5 (completion acceptance) (CAICT. 2020).

The platform provides multiple design options for comparison and selection as well as consultation and review services (Fig. 6.5.2). Multilevel and multidimensional comparisons can be conducted concerning spatial layout, building height, architectural style and related design parameters of the project design plan. Those consultation and review services can support both integrated two-dimensional and three dimensional displays. Through superimposition of general and detailed regulations on a three-dimensional design proposal, different design elements and strategies can be explored under different scenarios, to give a more in-depth experience and analysis of a design proposal, different browning methods, like aerial view, flying and wandering mode are provided.

Fig.6.5.2 Xiongan New Area BIM Review

Source: CAICT
https://pdf.dfcfw.com/pdf/H3_AP202012281444410282_1.pdf?1609160966000.pdf
mic-zone/

Taking the digitized planning and control requirements into account, automatic reviews of various design parameters of design plans can be carried out. This service is more than accessing the visual qualities of a project, it reviews and examines standards and dimensions regarding land area, main functional building area, building density… which are also important to a design proposal as its aesthetic.

Using AI to formulate urban strategies

Traditional smart cities tend to pay more attention to the smartness of a certain industry or field such as construction, transportation, water suppliers and landscape while Xiongan is based on CIM (City Information Model) (Fig. 6.5.3). With this platform, various professional data is integrated to achieve a new way of planning and design, building and supervision and city governance said by Liu Lifeng, Deputy Director of Planning and Construction Bureau of Xiongan New Area (The State Council. 2020).

A Digital Twin City has been built for the entire area of the Xiongan New Area. Because of this, all the three-dimensional images of the buildings can be displayed and they are as vibrant as a real city with dynamics, for instance, each single building constructed in reality can also be generated identically and simultaneously on its CIM platform; this also applies to a street lamp erected in reality.

The "underground" version of the Xiongan New Area can also be seen in its Digital Twin City*. Different integrated pipe corridors and intelligent control devices are deployed in it. After the completion of the Xiongan New Area, wires will not disrupt the beauty of the sky and manhole covers will hardly be found on the ground.

Fig.6.5.3 Planning and construction management platform of Xiongan New District

Source: CAICT

Using AI to manage construction

In the past, workers had to cut the steel bars by themselves resulting in some scrap material left. However, as the Xiongan New Area BIM system is adopted, calculations are done for all the buildings and the materials sent over can be assembled directly*, therefore, even one centimeter of steel bars do not be wasted. In addition, rather than going through a time-consuming reviewing process, steel bars ordering is done via Application at ease which saves time and human resources in such a process. The process of steel bar production can be tracked and understood in real time so a more accurate material arrival time can be predicted and to adjust the construction schedule timely and accordingly.

Since BIM systems are used, a quantification process has been done during a series of calculations, resulting in a more accurate material estimation and performance prediction for buildings and infrastructures. Drainage, intelligent sensors and other systems can be tested and simulated in the BIM system and these results can be used to optimise the design and proposal, plus multiple parties can collaborate and review the project simultaneously(Fig. 6.5.4), increasing a project's transparency which in return to achieve better coordination across different actors involved, reducing problems resulted from miscommunication, in short, stimulation can minimize unwanted surprises so to enhance the overall accuracy from imagination to realisation.

Moreover, Smart workers are employed in the construction site**, construction teams consist of smart paver and unmanned road rollers are working for the Jingxiong Expressway, these smart workers with different degree of artificial intelligence can perceive and communicate with each other to complete a twenty-one-meter wide one way lane construction at one go.

Fig.6.5.4 The display screen of the M+ Smart Site Command System of the Resettlement Housing Project Department of Group C, Rongdong District, Xiongan New District

Source: Huo Shaoxuan, Xinhua News Agency

6.6 From Scratch To Prototype

Xiongan New Area Digital Twin City is in full swing. JD Technology Group (JDTG)* has undertaken the project to construct the digital base, in other words, the block data platform adopted for Xiongan New Area Digital Twin City. The application of block data platform is wide-ranging supported by and thanks to its big data analysis capabilities which AI is one of the crucial ingredients in it. Engineering quality supervision system is an application and an example based on the block data platform.

There are more than 300 construction site tower cranes and more than 110,000 builders are working day and night in Xiong New Area. Behind the infrastructure construction, the engineering quality supervision system is adopted to ensure the safety and quality of construction (Fig. 6.5.5). This system can clean, process, analyze and integrate data in the process of engineering quality supervision, analyze hundreds of safety-related indicators from the data and help identify engineering quality risks. For instance, smart monitoring and cloud monitoring systems are adopted when working on some critical points like ringlock scaffolding, large hanging baskets, rotating construction… for the Jingde Expressway.

Fig.6.5.5 JD.com is just one of the tech companies racing to turn Xiongan New Area into the city of future
Source: JD Digits

https://www.scmp.com/tech/big-tech/article/3111653/jd-unveils-first-phase-xiongan-smart-city-operating-system-xi

Based on big data technology and a new generation of AI technology, the block data platform becomes the actual carrier of the urban big data resource center in Xiongan New Area, undertaking the significant task of converging all the data generated in the entire area, coordinating its data management and realizing the important task of data fusion application there. In other words, the block data platform is the data convergence center, data management center, data service center and AI empowerment center of Xiongan New Area.

The central government has stressed the significance of Xiongan New Area for many reasons. Wu Hequan says the significance of Xiongan lies in the ability to create a model city that can be replicated in the new era in cities that are not coastal and borderline in China, relying on innovation to drive development and blaze a path for high-quality development. Its demonstration has two meanings. First, it develops future-oriented high-tech industries; second, it explores new development models (Wan., Yu. & Qi. 2018).

Among them, to research a new form of urbanisation associated the most to the architecture related profession. In China, Digital urbanisation has been explored boardly and seriously in searching for solutions and alternatives to the problems found in the previous forms of urbanisation yet it is the first time to test in an actual context. Free from the constraints of an existing city, Xiongan New Area provides a blank paper and welcomes all sorts of imaginations and experimentations. As suggested by the name of the plan, Xiongan New Area is borned to be a long project, also an expansive one. In 2017, UBS Securities* expected Xiongan's total fixed asset investments to reach up to 4 trillion yuan over the next 20 years whereas Morgan Stanley forecasted the New Area could lure between 1.2 to 2.4 trillion yuan in investment over the next ten to twenty years, adding as much as 0.4 percentage points to economic growth every year**, making it the largest infrastructure project for Xi and possibly his successors. Since 2017, nearly 200 billion yuan*** has been invested in the New Area and around 30 key construction projects were completed.

Like most of the research projects, vision, talents, time and resources are the irreplaceable ingredients to success, undoubtedly, more criteria have to be considered but without them, the chance is slim. Simply by looking at the resources needed, this is not a project that can be easily replicated or adopted, therefore, with reference to the classification proposed by Anand that, like City Brain, Xiongan can be taken as an "utopian product of hyper-globalisation of capital" based on the huge cost of investment, resulting in an aspirational project (Anand, 2020).

Although there are still many years ahead to evaluate the success of the project: to develop a new form of urbanisation which is suitable for China, it is certain that those ingredients have to continuously be supplied in order to fuel the research. The vision of the project is clear but the outcome is yet to come.

Fig.6.6.1 Step up construction of key construction projects

Source: Liu Shuaiye, People.cn

http://pic.people.com.cn/BIG5/
n1/2020/0817/c1016-31824849.html

Fig.6.6.2 Photo taken at 2.00 am in August 2020 in Xiongan New Area

Source: Liu Shuaiye, People.cn

http://pic.people.com.cn/BIG5/
n1/2020/0817/c1016-31824849.html

Fig.6.6.3 (Top) Renders of Xiongan's Brain : Xiongan City Computing (Supercomputing Cloud) Center

Source: News.qq.com

https://new.qq.com/
omn/20210424/20210424A0ARJT00.html

Fig.6.6.4 (Right) Photo taken at 2.00 am in August 2020 in Xiongan New Area

Source: Xiong Yunwang Technology Co., Ltd,
People.cn, Rmxiongan.com

http://en.people.cn/n3/2020/1102/c90000-
9775714.html

CHAPTER 7|

A TOOL OR A THREAT?

In the last two chapters, two case studies, Hangzhou City Brain and Xiongan New Area are discussed comprehensively to understand their significance for now and future and relevance to AI. In this chapter, the focus is put on the insights gained from them mainly with respect to the research questions set at the beginning: would AI replace architects? If not, what will the architects be? As explained, AI has been applied in both cases yet owing to their contextual differences, AI's applications are not the same, at the moment, as an emerging first tier city, Hangzhou, Its Brain focuses more on the city management aspect while Xiongan New Area has still been constructed. All the distinct characteristics of these projects result in different needs of applications supported by AI even commonalities can still be found. After looking at the case studies, the potentiality of AI is further being recognized in the field of architecture and urban design, China is still the context concerning the following discussion, all possible aspects that are affected or would possibly be affected by AI to be talked through to answer those research questions. The complementary aspects are explained then followed by the potential substitutional aspects before weighting the overall impacts of AI on architects and urban designers.

7.1 Complementary

Research

In general, research is the starting point of an architectural project to comprehend all the possible dimensions it might face and encounter. Despite most of the dimensions being subject to changes, much effort is still dedicated to build up such consciousness. Gathering information is inevitably significant to understand the context, constraints, opportunities, rules, regulations and so on. In the traditional way, a lot of research work has to be done physically on site. For instance, taking photos, measuring, sketching or simply observing the surroundings. However, this preliminary stage in architecture has already shifted much of its work to the online world. The richness of data that the digital world offers enables all the architectural related professionals to tap into at anytime and anywhere.

An illustration named LUNCH WITH ROBOTS ATOP A SKYSCRAPER is drawn by Andrew Rae

Source: Andrew Rae
https://the-dots.com/projects/lunch-with-ro-bots-atop-a-skyscraper-75613
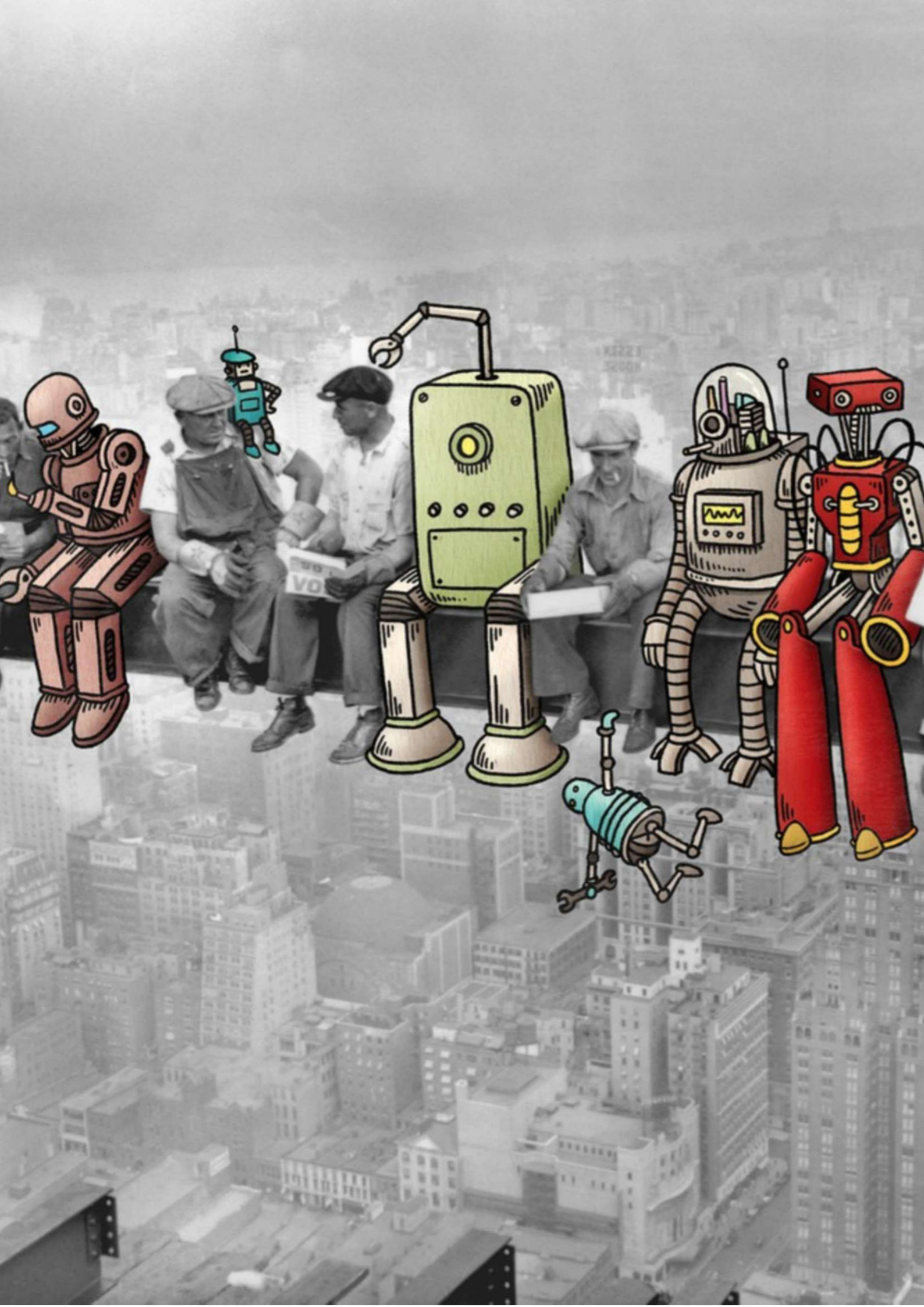
According to the recent official announcement published by the Hangzhou Municipality, one of the principles of City Brain is about people:

Always practice the people-centered development concept, insist on data resources that "taking from the people and using them for the people", highlight problems and demands and driven by them, proactively respond to the needs of the public and market entities, focus on user experience, carefully craft policies and various application scenarios such as services and funds that directly reach the grassroots, enterprises and people's livelihoods so to make people love them and enterprises feel amiable. (Liu, 2020)

People are supposed to be a key element in design so researching on people shall be an evitable task for designers. However, before the aid from AI, most of the time, designers rely on their instincts which are highly subjective, data which hardly be very updated and information which is not wide-ranging enough to explain human behaviour. With AI, data is not left around the city without meaning. The data harnessed by Hangzhou City Brain are used to facilitate the research process and its future development. With the help from the digital infrastructure, records and data related to human behavior and interactions have been amassed in the Cloud by thousands and thousands of devices appeared both online and offline, AI is able to discover patterns out of the data and possibly provide new insights and reveal some hidden behavior found in the city, the socialistic side of a project thus can easily be taken care of remotely and more accurately.

Looking at the bright side, these would underline the human presence in the design by considering and integrating the needs of end users. For instance, City Brain gives practical insights to architects on how to create a city which is more contextual to both the environment and its citizens. The Digital Twin City supported by the data provided by City Brain is another breakthrough in helping architects to understand the existing city better during the research phase.

To conclude, in this stage, AI mainly facilitates building up a strong foundation of understanding for a project by providing a panoramic view with multiple perspectives thanks to its ingenious analytical skills and its impressive database.

Design

Pete Baxter, Vice President of Digital Manufacturing at Autodesk says "There is a paradigm shift now: the one-man architect working from home with a bright idea now has access to an infinite amount of computing power in the cloud. That means a one-man designer, a graduate designer, can get access to the same amount of computing power as these big multinational companies." (Meltzer, 2014) Autodesk is a key provider of digital solutions to the architectural and construction industry, not surprisingly, it underlines the power of computing. In China, reflected on its Xiongan New Area's construction and other projects, digital solutions powered by AI have also been underlined and incorporated into the design stage.

AI-assisted BIM has widely been adopted in constructing Xiongan. Since the early 2000, BIM has already provided alternative ways of working to architects and to the industry. The core of BIM is to establish a virtual three-dimensional model for a construction project with accurate data, to provide the model with a complete set of databases, including engineering, costing and other related information which is consistent with the actual situation. In other words, as its name suggests, the 3D model contains a lot of information and data. With AI, the capacity of BIM has further been stretched and explored thanks to its ability to analyse, to learn from the data and detect patterns. Such machine learning capability allows BIM to enhance its performance and work independently.

This system serves as a unified platform for all the actors involved in the project, the logic is similar to unify a language for everyone to use for the sake of better communication. (Fig. 7.1.1 & 7.1.2) No matter in terms of architectural or urban scale, there are a vast number of people participating in a project, therefore having a common ground is very relevant to achieve better coordination and consistency. This common language has been built up for Xiongan New Area development. Six phrases (e.g.BIM0, BIM1, BIM2…) are classified to carry out different functions throughout the building's lifecycle.

Rather than simply being a digital data storage of the models, BIM knows how to propose possible solutions based on criteria and inputs. This function has been applied in designing Xiongan, giving more design options to the architects. The cognitive capability possessed by the system allows it to review the designs, not only to avoid mechanics, engineering. plumbing …clashes, it evaluates if the designs can meet other requirements, no matters general requirements by law or specific requirement by clients. Although more might not be better, it gives more possibilities for people to choose.
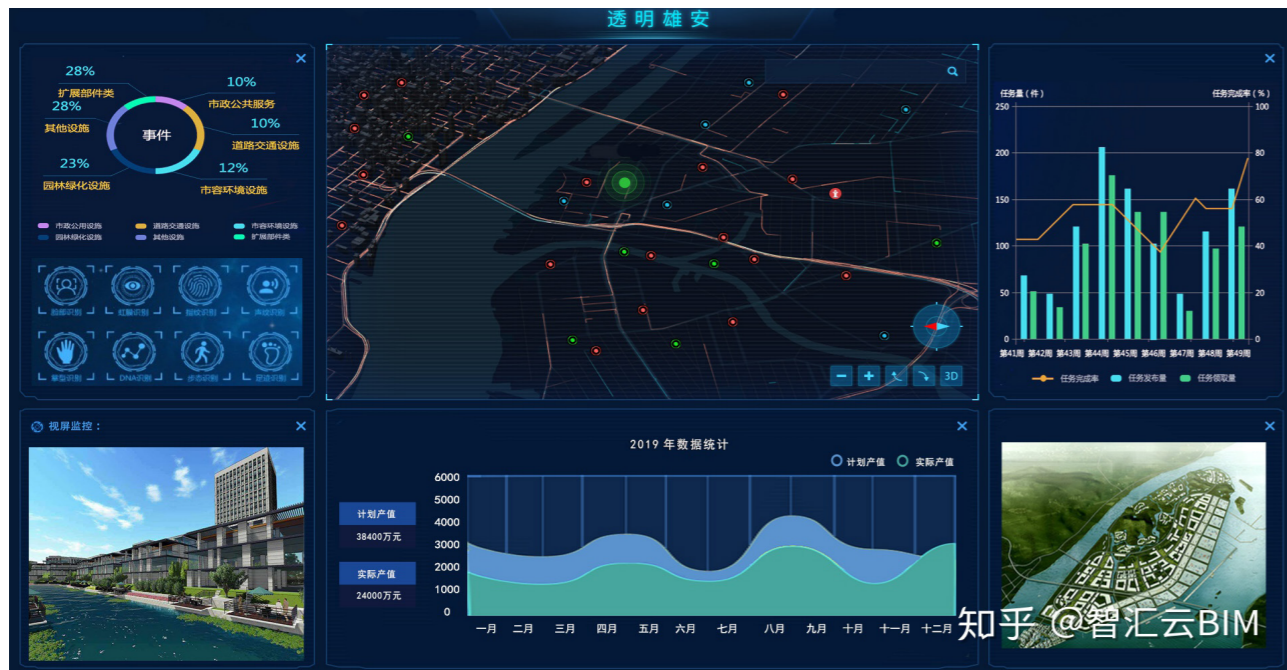
Fig.7.1.1 (Top) "Transparent Xiongan Digital Platform", putting the entire construction site on the screen

Source: 智汇云BIM, Zhihu
https://zhuanlan.zhihu.com/p/138453746

Fig.7.1.2 (Below) The Digital Platform provides 24 hours real-time control of the construction site (shown on the top right corner) and analysis of the site, such as temperature (shown on the bottom right corner)

Source: 智汇云BIM, Zhihu
https://zhuanlan.zhihu.com/p/138453746

Simulation is important during a design phase where architects test their fantasies virtually, having a deeper understanding on the practicality of a concept. BIM can perform different types of stimulation, reducing unexpected and undesirable surprises. A lot of simulations are conducted for Xiongan's infrastructural and architectural constructions, like the railway, the railway station and Xiongan Business Service Center. After the Digital Twin Models of the design go through the simulations, results generated can be used to improve the design, like detecting possible clashes and errors. Clashes are common without a smooth integration of various disciplines. If clashes can be identified in the design stage, adjustment can be made to avoid mistakes during the construction stage. Reviews and comments made by other departments can be made simultaneously to further optimise the design and more importantly to mitigate safety and risk.

Construction

AI's footprints can be seen in Xiongan's construction site (Fig. 7.1.1). Rather than assigning all tasks to AI, Xiongan is a testing point for the technology before mass application. Xiongan Citizen Service Center is the first large-scale urban construction project after the establishment of Xiongan New Area. The Technical Director of Xiongan Citizen Service Center, Ye Jian says more than thirty new construction technologies have been adopted for the project which is the first time in the history of Chinese civil construction. (Bai & Li, 2018) The determination to build a Future city is stated clearly by the government, it is expected that more new construction technologies will be applied in the upcoming projects to digitalise and revolutionise the constructions which have been stigmatised as old-fashioned in many senses for many people and for centuries.

Besides being old-fashioned, the construction industry is seen and has been proved to be dangerous, therefore, different measures are adopted to enhance the safety in the workplace with the aid of the technology, for example, using BIM Immersive VR to let the workers have an interactive experience and education about on-site safety*. Another example is to use AI during the construction of Xiongan Citizen Service Center**. AI can help implementing some strict safety management measures. In addition to providing safety training and equipping front-line workers with intelligent helmets, a safety production emotion recognition system was also introduced for the first time in the Chinese construction industry. When a worker stands in front of a camera, the system records the tiny amplitude and frequency of his facial muscles, calculates and analyzes his potential emotions, then to adjust work arrangements for workers who exceed the limit to work at height or at edge, therefore, to minimise the risk of the workers.

After all, it is expected that more applications will be created for enhancing the on-site safety and efficiency and tackling the problem of insufficient construction workers. Even these will not directly affect architects, still, no matter what tasks are, anyone who has to carry out their duties on site becomes safer is always desirable, plus a safer workplace can boost up the confidence and efficiency of the workers, in return, being beneficial to the project.

* https://zhuanlan.zhihu.com/p/342741119

** http://www.chinaxiongan.cn/n1/2018/0424/c418882-29947114.html

Technology has improved the architectural managerial tasks in many possible aspects. BIM is an obvious example showing how technology can reduce some management workload in some tedious tasks, allowing them to focus their energy on more critical aspects or unexpected issues of the project. During the way to construct the Future city, AI-aided technology has been penetrated in some management work.

In the control room of the Xiongan Citizen Service Center project, aerial images of the construction site taken by drone can be retrieved at any time and the QR code can be scanned to view the VR panorama, the progress of the project, the number of personnel on the construction site, real-time environmental monitoring data can be clearly presented through the big data center. Thanks to AI, these drones can be flown around the construction site autonomously and freely, taking images or videos and providing real-time information for the control and management teams.

The rising popularity of CIM or a Digital Twin City further expands the practicality of AI on a broader scale. City Brain makes the construction of Hangzhou Digital Twin City possible; this virtual platform enables people to manage the city more effectively and efficiently, at the same time, it provides architects deeper understanding not only on how to design but also to manage an architectural or urban project in an all-rounded manner, having a better coordination among different concerned parties. Plenty of information is built up inside the three-dimensional model space, from an architectural scale to an urban scale, with all the relevant information not restricted to man-made constructions but also the nature, because of these, architects are more informed about the context, able to propose solutions promptly and coordinate accordingly in particular in face of emergency.

Ability of narrow AI is limited but with continuous technological advancement or even breakthroughs enhance the cognitive capability of deep AI technology. In other words, concerning its ability, AI is no longer being restricted to repetitive and tedious work, it is anticipated that it can carry out more tasks in the future. Still, does it mean they can substitute architects in any aspects?

Research

Research is a preliminary step of a project. When commencing a project, architects have to know the requirements set by the clients besides all the government restrictions. Although there are references showing architecture is an artistic and highly personal expression of the designers, the contextual design approach has had many believers and supporters, conserving and continuing their beliefs by executing them in a real three-dimensional space. "My job is to try and understand where the architecture will be situated, how it will be rooted, and what sense it will make where it is." Pritzker Architecture Prize winner, Jean Nouvel speaks about his belief. (Louisiana Channel, 2014) Renowned for its contextual approach, he points out understanding is the key. Research is a way to investigate, to learn and to understand a certain topic and to reach conclusions which means it is the way to get that "key".

When looking at the Hangzhou City Brain case study, as discussed, without City Brain, this useful material is left around the city. AI makes the research process faster and easier by making data, information and analysis available at real-time and at ease. The reason to conduct research for an architecture or urban project is for architects to understand the context as simple as that. Therefore, AI assists them to understand it better and faster by simplifying and shortening the process, ultimately facilitating the decision- making made by the architects.

Unless the research process is directly linked to the design process which means the research result is directly fed to the programs for generating design options, otherwise human presence is always there during the research stage. Based on the two reference studies, it is not the case in China, AI is adopted to assist designers to understand the context better rather than giving them the ability to take over the decision-making role from the people, deciding which are the aspects to be focused on or not.

Design

In Xiongan New Area, BIM is a common ground for designing a building whereas CIM for designing an entire city. Those advanced programs, in certain ways, powered by AI, upgrade their functions and features for architects. References show BIM generated design options based on pre-set criteria but no evidence shows they are used for actual construction.

AI has the ability to create, however, it does not mean architects can be absent from now on because people are still relevant in determining the criteria for computation and for the designs. Undoubtedly, deep AI can learn and to respond but people have to tell them what to learn.

Xiongan case study shows AI can generate but it does not know what to generate without human intervention. Moreover, it does not show any tendency to allow AI to make decisions all alone. At the end, it helps to review the design to avoid human errors but humans give the final conclusion, no matter on what to focus and to choose. Although the design part is not entirely substitutable now, looking at those examples, interests on this matter have been shown through research and experimentations. It is expected that less architects will be assigned to drafting or drawing for a project and efforts are concentrated on understanding the criteria and explaining them to AI what to do.

Fig.7.2.1 The Jingxiong Expressway unmanned cluster intelligent construction observation meeting was grandly held in Xiongan, Hebei.
Source: 21 - Sun
https://ppfocus.com/mo/0/dee5c48.html

Construction

Autonomous vehicles use artificial intelligence systems which employ machine-learning techniques to collect, analyse and transfer data to make decisions that in conventional cars are taken by humans*. This technique has also been adopted in the Xiongan's construction site. The strategic development of Xiongan New Area emphasizes on its connectivity, a lot of constructions in the first stage related to enhancing its physical connections with the Capital city and surrounding first-tier cities through highways and high-speed trains. One of the highways, Jingxiong Expressway**, its two inner lanes are dedicated to driverless driving and this is the first time in the world that an autonomous construction machinery cluster is used for constructing lanes for autonomous driving. Such an intelligent equipment cluster composed of three pavers and six rollers completed the paving and compaction of the highway stabilized soil autonomously (Fig. 7.2.1). Equipped with the Beidou positioning system, which collects surrounding environment information through the sensor equipment installed on the vehicle, those machines can optimise operation path according to the environmental parameters, automatic warning, emergency parking and automatic obstacle avoidance can be achieved. Regarding safety protection, the accuracy of its construction trajectory can be controlled at 2 to 3 cm which is 50% higher than manual operation.

Physical construction of a project is beyond the scope of being an architect. Some architects have the responsibility to manage the construction of a project to make sure their designs are executed properly, however building a physical wall is more a duty of construction workers. AI has improved the safety of the workers on construction sites in different ways, the discussed autonomous construction equipment can minimise the risks by eliminating the human presence during the work process.

The technology of using autonomous construction is used in Xiongan and expected to be seen in other construction sites in China. In other countries, such as Japan, this type of autonomous technology has started to become popular in the construction industry. Not surprisingly, it is very likely to see high-risk jobs taken over by AI from the construction workers' hands.

* https://ec.europa.eu/jrc/en/news/cybersecurity-challenges-uptake-artificial-intelligence-autonomous-driving#:~:text=Autonomous%20vehicles%20use%20artificial%20intelligence,cars%20are%20taken%20by%20humans.

** https://ppfocus.com/mo/0/a2ac943.html

Management

From concepts to construction, to realise a virtual building or a city, drawing is only one of the tasks of the architects. To bridge the gap between virtuality and reality, a lot of work hours are needed for coordination and management. With AI, those work hours originally devoted to those duties can be reduced, again, dedicating more time to other issues which it is less capable of.

City Brain has done a lot for Hangzhou city in terms of various aspects, its traffic, security, tourism, healthcare, emergency services…to lessen its problems and to improve people's quality of life. The contributions of City Brain are largely related to city management and AI is a climacteric element in offering solutions regarding this, yet, managing a city is not so relevant to architects.

For the current stage, unlike Hangzhou, Xiongan New Area is still emerging. Possible scenarios and applications armed with AI have been explored. When managing an ongoing mega project, like those in Xiongan, apart from the head of the team, there are layers of hierarchy supported by workforces. The computational and analytical powers coming from AI have reduced the time spent on making analysis manually. Combining those analysis with other systems have resulted in both time and labour-saving tools.

A digital platform used in the smart construction sites in Xiongan New Area combines the AI-aided BIM technology, cloud computing, IoT and other technologies together, because of this unified platform, a lot of instant information and data can be retrieved when needed, plus other functions are provided "instinctively". Linked with on-site environmental monitoring equipment and spray dust reduction devices, an environmental monitoring and intelligent spray control system can start spraying automatically when the set threshold is exceeded. Other automatic alarming systems, such as the construction elevator safety monitoring system which provides real-time monitoring of its operation*; construction site border and cave entrance protection system which can alert people about themselves or objects that are close to the border or crossing or breaking into the cave entrance and the unloading platform safety monitoring and early warning system which alarms automatically when an illegal operation occurs. The roles originally taken by real employees can be and have been replaced by the discussed systems despite less people are willing to work for those tasks.

The case study of Xiongan New Area shows certain roles are substitutable by the systems aided by AI. However, these duties do not fall within the job descriptions of being an architect who is responsible for managing a project. In contrast, AI helps them to understand the construction status better with instant information provided because of the constant monitoring devices and computations. Moreover, human presence is still essential to participate in meetings, to discuss and coordinate issues related to the project. To sum up, rather than taking over the managerial role from an architect, it has instead occupied repetitive tasks without much decision-making skills required.

7.3 Complementary or Substitution?

AI reminds an intelligent tool

What AI has done for the city is undeniable and its help to architects is getting more relevant and prominence day after day, yet it reminds a tool for people who are able to see its potentiality and apply it accordingly to reap the benefits. Related to the Chinese case studies discussed in the paper, it is expected that in the specific Chinese context, there will be more AI-aided applications but AI is kept as a tool adopted to help architects rather than replacing them with the technology completely. "Yes, you can automate. But what does a design look like that's fully automated and fully rationalised by a computer program? Probably not the most exciting piece of architecture you've ever seen." Pete Baxter says. (Meltzer, 2014.) It is understandable that its intelligence might be overwhelming at first after looking at its contributions and abilities. However, when taking a deeper look, there are still many qualities required to be an architect and some of the fundamental qualities are not possible to substitute with AI entirely.

More technological breakthroughs are anticipated to advance AI's cognitive ability which is the quality that makes people worry about. However, AI still lacks sensibility which is crucial to being an architect or a designer. Sensibility is not about intelligence but feeling. It is true that feeling can be imitated by AI through machine learning but the true essence of feeling cannot be created even for human beings to explain. Jack Ma, the co-founder of Alibaba, once said, machines can never win [against] human beings, adding that humans have hearts while machines only have chips. (Driscoll, 2017.)

Tasks associated with repetitive or tedious, dangerous or risky which also are more likely to be considered as undesirable, these are the domains that people are willing to invest and investigate into, turning them into less undesirable by improving the working conditions or minimising the contributed hours or even finding ways to replace them. Referring to the case study of Xiongan New Area, a lot of tasks that became autonomous are likely to belong to one of the categories. AI does replace some of the workforce but after balancing the costs and benefits, it might be a better option to let AI take over the job.

Moreover, the emerging capabilities of AI explained in the Xiongan case study, such as generative design options and review ability, unquestionably, the future workforce focus mainly on these tasks will be shrank. Although they have these abilities to do these tasks, they still need support from people, for instance, to set up the basis for AI to work by instructing them requirements and criteria. Some tasks are replaced by AI while some remain, in short, the focus of the architects is concentrated heavily on understanding the problems, managing, coordinating and strategic planning instead of solving the problems manually in the AI era.

Unless the tasks concerned the daily operational things that do not affect the overall strategic direction of a project, people allow them to make their own judgement and decision, like when to change the traffic light or when to alert the workers not to work at height, otherwise, major and critical decision-makings are still at the hand of a human being. Same for the architects who will be free from repetitive tasks, such as the discussed drafting and reviewing, nevertheless, they have to make decisions and judgements, for instance, what architectural style or material to propose to clients. These would affect the overall design direction which AI will not be allowed to decide.

The Chinese government mentioned its economy has to go towards high technology so it has been providing different kinds of support strenuously. (Fig.7.3.1 &7.3.2) Exploring AI and its applications are perfectly in line with its strategic direction and those "explorations" require specifically trained or educated and skilled labours. Although architects for now would not be replaced completely, with less tasks required to do manually by them, there are still implications on the original workforce. It is highly probable that either not as many architects are needed for the industry or the workload to be spread among them. AI enhances both the efficiency and effectiveness of the industry, at the same time, it affects its labour market and allocation of labour.

Fig.7.3.1 Rendering of Zhongguancun AI Technology Park which can house up to 400 AI companies.
Source: Zhongguancun AI Technology Park
http://www.zgc-aipark.com/index.php?m=content&c=index&a=show&catid=11&id=278

Fig.7.3.1 Rendering of Zhongguancun AI Technology Park, located in the western beijing
Source: Zhongguancun AI Technology Park
http://www.zgc-aipark.com/index.php?m=content&c=index&a=show&catid=11&id=278

A comic strip titles Robot is drawn by Elizabeth Pich and Jonathan Kunz

Source: warandpeas.com

CHAPTER 8|

REFLECTIONS

From understanding the practical applications of AI in architecture and urban design through two real cases studies taken from an urban Chinese context to analysing its possible impacts on employment in different perspectives. In the final chapter, some reflections are made.

As more and more people see themselves displaced by machines, they will be forced to answer a far deeper question : in an age of intelligent machines, what does it mean to be human?

Kai Fu Lee (Lee, 2018, p. 147)

I asked myself similar questions when I saw Sebastian Errazuriz's comments on the future of being an architect. After months of research on this topic, my reflections are summarised to contemplate the meaning and role of being an architect, especially in the Chinese context during the age of AI.

8.1 A Chip And A Heart

Based on the research conducted for the selected case studies which are representative for current urban development in China, these examples show the impacts on the labour market are expected with different degrees of disruption. Although it is concluded in the last chapter, architects will not be substituted completely, restructure of the labour market with reallocation of resources, including human resources are expected. What are the hidden implications of the restructuring and reallocation means to would-be architects and those who are already in practice?
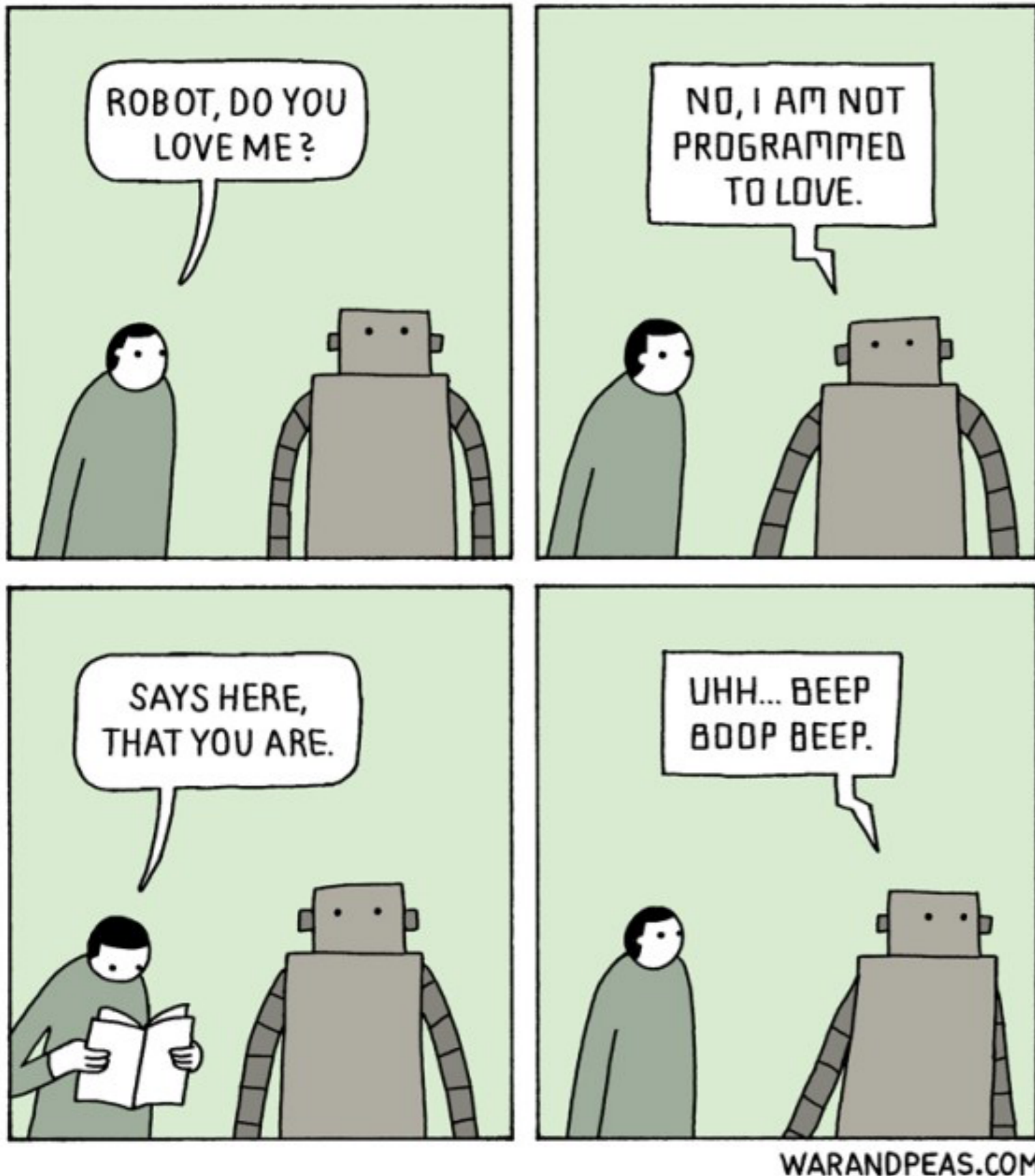
Generative design approach, this design exploration process has already seen its debut in the Xiongan New Area project. Although It is still in its infancy in China, its potential and upcoming applications are expected to be vast which would possibly trigger reallocation of human resources, for instance, the amount of work hours needed for drawing thus to execute ideas will be reduced. An entire project, the new Autodesk offices in MaRS District, adopted this approach and was realised in Toronto in 2017*(Fig.8.1.1). AI-power software that support the generative designs can be found in the market, such as Space Syntax, Delve and Dreamcatcher. In China, founded by a group of architects and software engineers,xkool is also a generative design application developed for the market**.

* https://www.autodesk.com/autodesk-university/article/Hands-Project-Rediscover-Generatively-Designing-Autodesk-Toronto-Office-2020

** https://www.xkool.ai/

These examples show its potentiality for mass application is no longer too far to be imagined.

Generative design is one of the aspects that AI's applications and competencies can handle superbly. Undoubtedly, no matter willingly or unwillingly, AI will take the lead in those domains which require minimal human interactions but demand for data interpretations and analysis, particularly for the companies focusing on urban projects, more complex contextual analysis can be handled by AI. Therefore, instead of turning a blind eye or immersing themselves in the past glory, architects have to get prepared for the transition and upcoming transformation, be ready to delegate those repetitive, tedious, data-analytical and compassionless tasks to AI, unless they devote themselves into certain special scenarios, such as protecting the traditions in rural contexts. Continuous education and training are salient ways of self-preparation, AI is an intelligent tool and it requires our intelligence to learn using it at work. Like passing from manual drawing to digital drawing when CAD was invented, there must be someone holding on to the "traditions" but obviously, it is not the common practice found in the industry.

Skills that were seen as irrelevant to architects will become more relevant as the tools to design have been evolving. Coding and other technological know-how are required from a growing number of roles. It is not surprising to see more cross-disciplinary professionals who will engage in the architecture and urban design, to bring freshness into the industry. There are already some examples, like Zaha Hadid and Thomas Heatherwick, who challenged the industry with their creativity. More examples are expected to be seen in the future as AI is a robust tool, allowing people to tap into architecture and urban design even without specialized training.

Fig.8.1.1 Autodesk MaRS Office designed by The Living using generative design
Source: Ben Rahn /A-Frame
https://www.architectmagazine.com/project-gallery/autodesk-mars-office_o
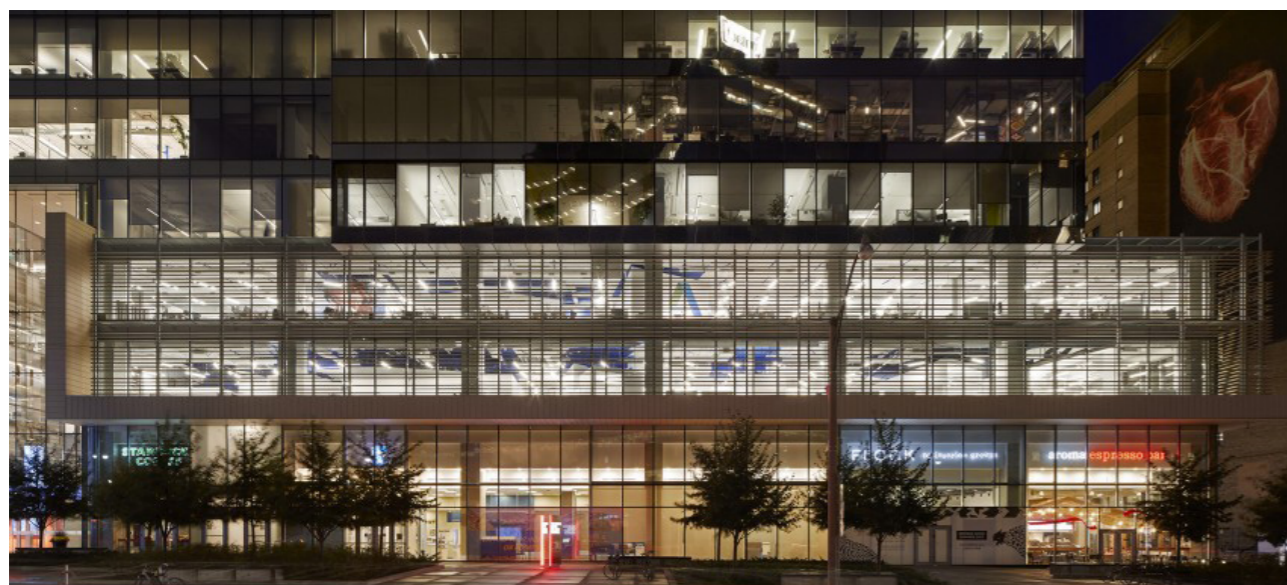
Knowing what AI is good at and what it is not, it is pivotal for human beings to further develop and strengthen the qualities which we are good at but not for AI. Ka Fu Lee pointed out that AI can optimise but cannot create (Fig.8.1.5,6 & 7). He further explained: AI has far surpassed humans at narrow tasks that can be optimized based on data, it remains stubbornly unable to interact naturally with people or imitate the dexterity of our fingers and limbs. It also cannot engage in cross-domain thinking on creative tasks or ones requiring complex strategy, jobs whose inputs and outcomes aren't easily quantified. (Lee, 2018, p. 155)

The required skills of being an architect are inevitably complex. It is always said to be a profession of the perfect combination of art and science, the humanity rooted in architecture or being an architect deserves more attention and emphasis. As AI is unable to possess true feeling and emotion, architects have to spend more time on building-up their sensitivity, not only for mankind but also for nature. Being an architect is more than coming up with design options and drawings, there are many other tasks which require architects to do, like to manage, to explain, to communicate with and to care for the people, society and nature. Various degrees of compassions and interpersonal adroitness are essential to carry out their duties. As it is not a purely data-driven and analysis job, the opportunities will be reserved for those who can excel in those areas which cannot be replaced by AI.

AI has the exceptional potentiality and ability of revealing things that we are not aware of as explained in the City Brain example whereas architects are supposed to be shone at creating, understanding and caring. Rather than fighting against each other in the arena, architects have to know their advantages and focus on the importance so AI can complement their works which become more sustainable for nature and people. "I think it's important to create spaces that people like to be in, that are humanistic." Frank Gehry tells one of his fundamental philosophies of being an architect. He continuous, "There's not enough humanity in buildings... it doesn't have to be in curves, it can be in boxes. They can have feelings!" (Raja, 2012). For those upholding and protecting the belief of co-existence of humanity and sustainability, they will never be substituted by AI since it is unable to feel, let alone to love.

Inspired by Kai Fu Lee in his closing chapter : If we believe that life has meaning beyond this material rate race, then AI just might be the tool that can help us uncover that deeper meaning.(Lee, 2018, p. 230) To me, If architects believe they have a humanistic role then AI just might be the tool that helps them to pass on their missions and to architect their intelligence through creating better space and experience for the people.
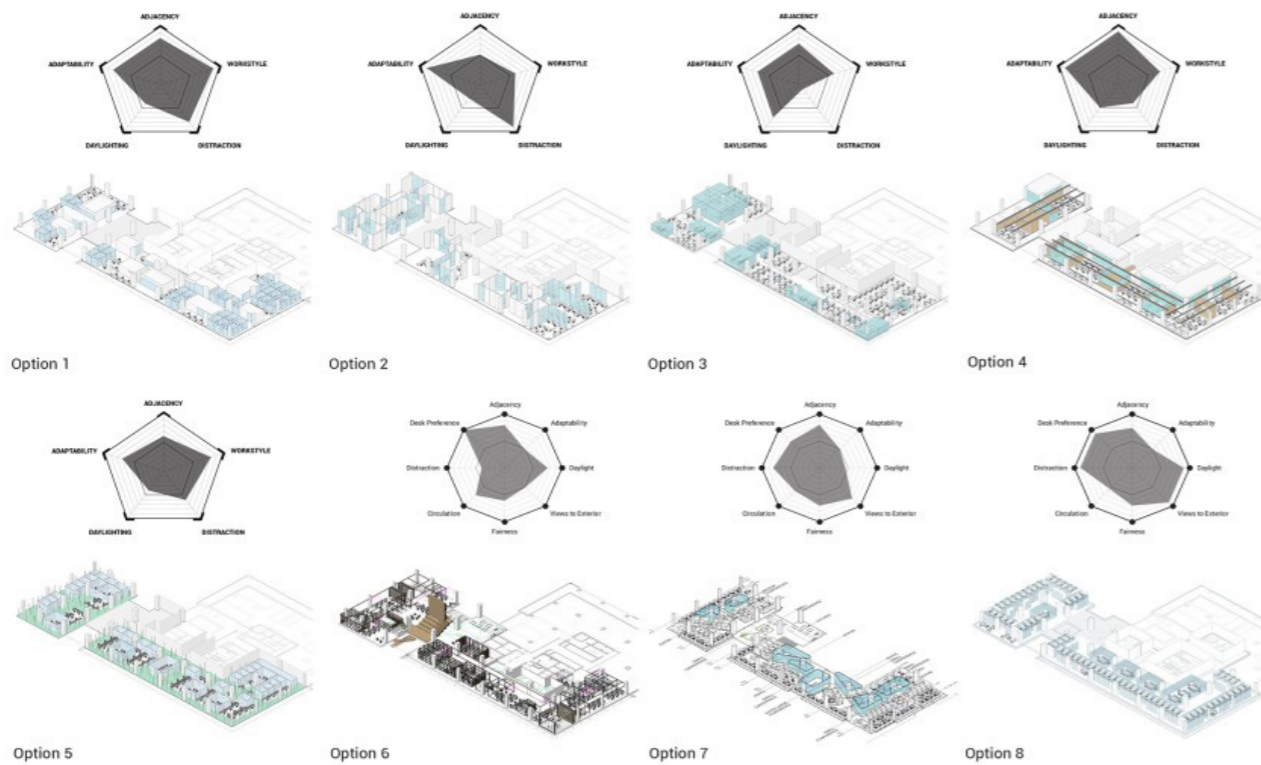
Option 1   Option 2   Option 3   Option 4

Option 5   Option 6   Option 7   Option 8

Fig.8.1.2 Generative design options for the Autodesk MaRS Office

Source: The Living

https://www.architectmagazine.com/
project-gallery/autodesk-mars-office_o

LOW DISTRACTION

WORK STYLE
PREFERENCE

ADJACENCY
PREFERENCE

VIEWS TO
OUTSIDE

BUZZ

DAYLIGHT

Fig.8.1.3 Criteria set for generating design options

Source: The Living

https://www.architectmagazine.com/
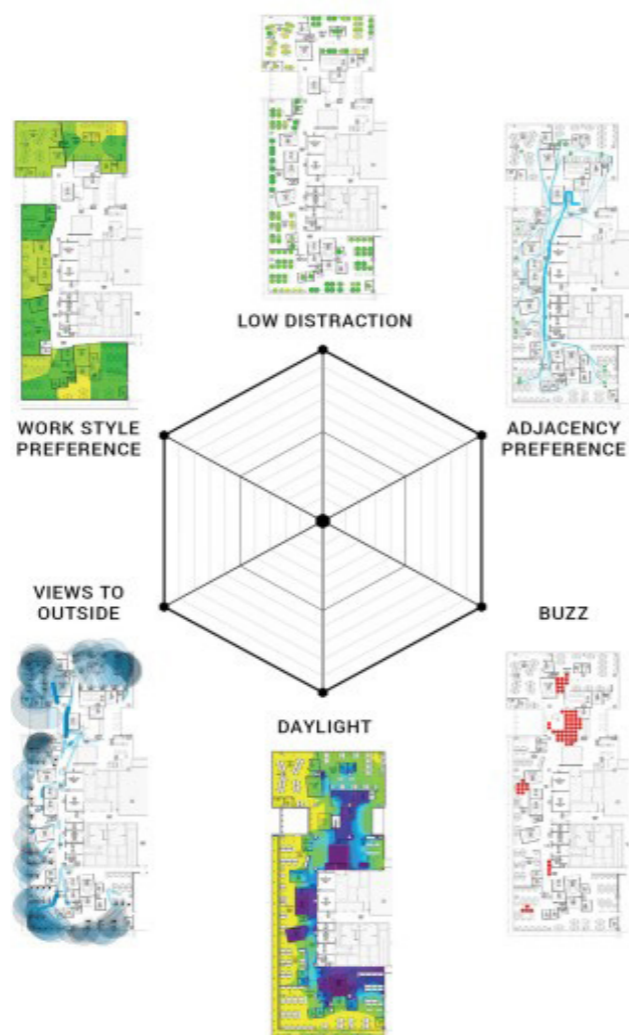project-gallery/autodesk-mars-office_o

Fig.8.1.4 The generative design process for the Autodesk MaRS Office

Source: The Living

https://www.architectmagazine.com/
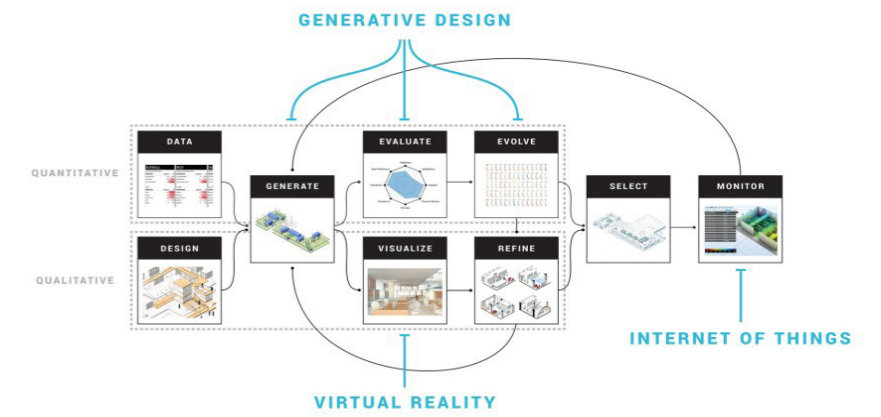project-gallery/autodesk-mars-office_o

Fig.8.1.5 How different types of occupations are at risk of AI disruption on a timeline

Source: Kai Fu Lee's TED talk

https://medium.com/value-stream-design/
why-china-may-be-the-next-ai-superpower-
part-ii-cdb07fbcc5c8

Fig.8.1.6 Professions of compassion (y-axis) and optimization vs. strategic (x-axis) as a basis for differential future in the AI age.

Source: Kai Fu Lee's TED talk

https://medium.com/value-stream-design/
why-china-may-be-the-next-ai-superpower-
part-ii-cdb07fbcc5c8

Fig.8.1.7 In future, the four quadrants of human and AI division of labor will look like this when superimposed with the previous quadrant

Source: Kai Fu Lee's TED talk

https://medium.com/value-stream-design/
why-china-may-be-the-next-ai-superpower-
part-ii-cdb07fbcc5c8

APPENDIX
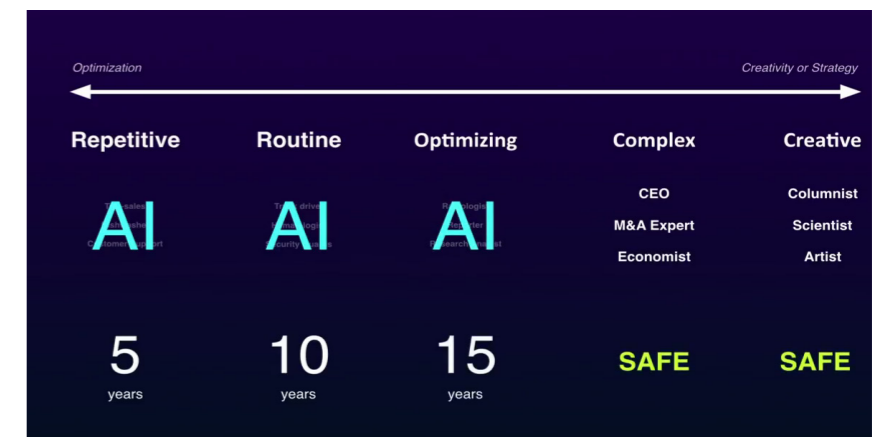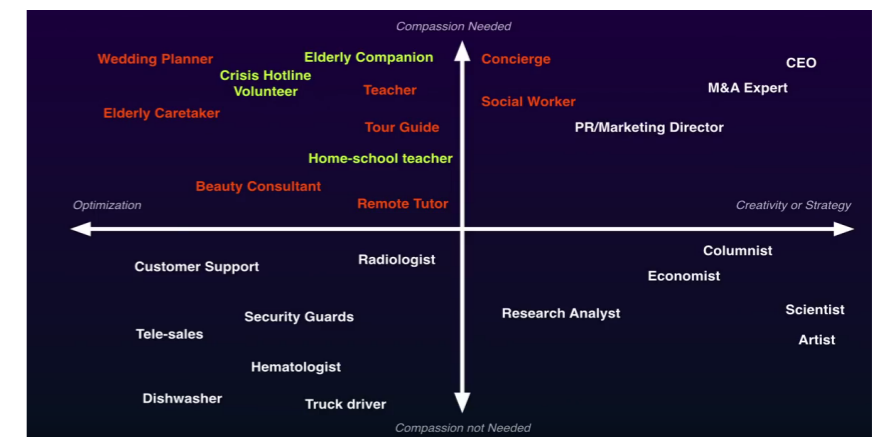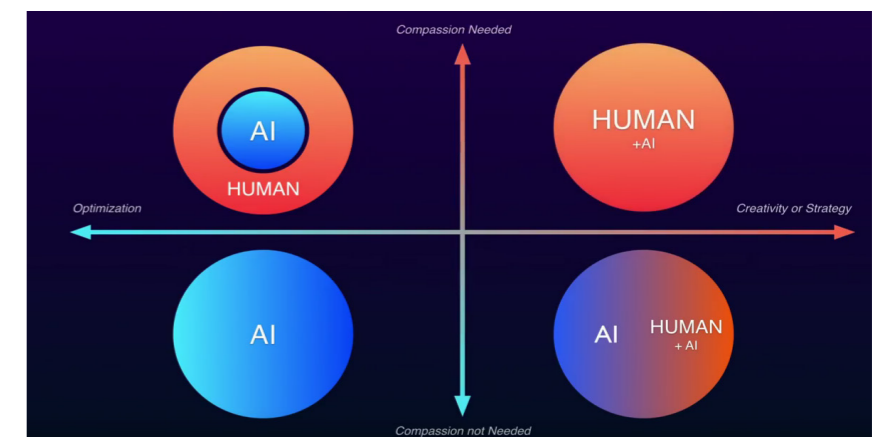
Generative Adversarial Networks

We propose a new framework for estimating generative models via an adversarial process, in which we simultaneously train two models: a generative model G that captures the data distribution, and a discriminative model D that estimates the probability that a sample came from the training data rather than G. The training procedure for G is to maximize the probability of D making a mistake. Generative Adversarial Networks, 2014

The operation and interaction between generator and discriminator is a back-and-forth process. The image would be created, assessed, recreated, reassessed... Through a self- correcting feedback loop, a level of accuracy is secured when the images are generated from neural networks with GAN technology. Its power in creating relevant images can be gradually enhanced by learning through time above all its competency in accumulating its database.

AI was mostly an analytical tool before his ground-breaking research was published. Thanks to him who opened a new domain for AI, having a new role as a generating agent, therefore a wider and closer role in the field of architecture owing to its competencies in design and image production.

Dreamcatcher is an example of applied generative AI technique and research project. Originally targeted at the industrial design and automotive industries, recently trying to tap into the architectural market, it is a cloud-based 3D design software that grants designers the ability to programmatically optimize 3D CAD designs. CAD models of the surrounding site and other wide spectrum of design input data, including information about the environment, clients, formulas, engineering requirements, CAD geometry, sensor information and so on are fed into the processor. Then a series of optimized 3D design solutions which are ready for rendering are produced by the system minutes later. Self-learning algorithmic parameters are the bases for creating multiple options and those processes count on the effectiveness of cloud computing.

Spacemaker

AI-powered generative design offers an alternative to the conventional practice which existed in the industry for long, its augmented ability helps architects or designers to compress those protracted processes as described, to solve most of the complex multidimensional optimization problems related to design in an urban area. "We set out on a mission to help, engineering and project teams reinvent the development of more sustainable cities and neighborhoods worldwide while maximizing the investment." (Harrouk, 2020) Harvard Haukeland, co-founder of Spacemaker, shares his mission on creating game changing AI technology for the industry. Using AI to integrate multiple factors and scenarios, the cloud-based software Spacemaker helps the creative professionals to design and make the best decisions about what and how to build on the site. Taking all relevant concerns into account for the development, including all the environmental factors such as terrain, sun and wind conditions, government regulations, zoning, personal preferences and on, unlike the common practise which is still being siloed, this digital tool empowers designers to access to all relevant data thus adapt to changes dynamically instead of using various fragmented tools for analysing the context and assessing the concepts separately. Therefore, the time spent on creating and testing urban design ideas can be significantly reduced, the generative ability of Spacemaker can rapidly create and evaluate options respecting the defined parameters for the project. All the tradeoffs are shown alongside the proposed ideas, giving a more complete picture to decision-makers, even some criteria are adjusted, both the positive and negative effects are re-calculated then depicted of those changes accordingly. More situational analysis can be carried out to be more informed and prepared for the risks associated with the designs. Again, the financial aspects which are usually not too integrated into the design but very much concerned by investors are now combined.

Fig.A.1 Spacemaker Proposes AI-Powered Generative Design to Create More Sustainable Spaces and Cities

Source: Spacemaker /Archidaily

https://www.archdaily.com/952850/spacemaker-proposes-ai-powered-generative-design-to-create-more-sustainable-spaces-and-cities/5fcea4f163c017fc5100011f-spacemaker-proposes-ai-powered-generative-design-to-create-more-sustainable-spaces-and-cities-image?next_project=no
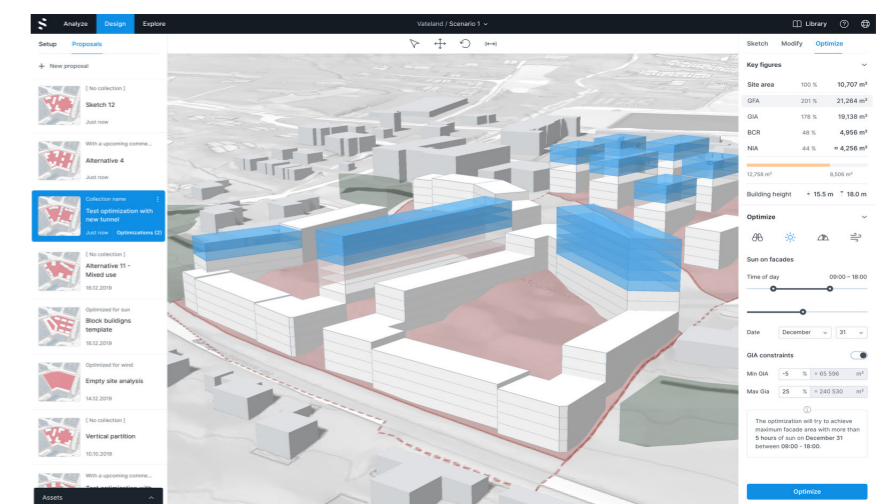
CityScope

Suggesting an innovative methodology of interaction and collaboration, City-Scope provides the opportunity of stimulating the impacts of interventions on urban ecosystems before the detail-design and implementation. For the tools developed and deployed by them globally, most of them remain free and open for the public. The "NICE2035 LivingLine" done in Shanghai is one of the CityScope's projects. For this crowdsourcing project, MIT Media Lab's City Science Group collaborated with Tongji University, sharing a common goal in building an ecosystem of innovation and entrepreneurship on the internal street of a typical gated residential neighborhood. Employing the most updated machine learning and computer vision technologies to quantify urban metrics via WI-FI camera data thus to understand deeper its urban vibrancy and potentiality concerning urban innovation. After that, to analyze the impacts resulted from urban interventions on urban vibrancy through computation. Lastly, a predicted model was born to drive a system of urban decision support, aiming at helping different actors involved to make decisions collaboratively and based on evidence. In short, these social engagement initiatives and tools to direct urban design can avoid solutions which are isolated from the concerns of the community and might be too ideal to be true.

FaceLift

Developed by scientists at Nokia Bell Labs Cambridge, FaceLift is an AI framework that automatically beautifies urban scenes by combining recent approaches of GANs and deep convolutional networks rather than simply conducting an assessment. (Alonso. et al., 2018)　The deep learning network can beautify existing urban scenes and explain which urban elements made those transformed scenes beautiful. (Joglekar. et al., 2018) People can redesign the look of city streets adopting a crowd's aggregated sensibility.　AI algorithms learn from known preferences rated by humans then those ratings are transformed to absolute ranks, after computation and analysis are done, insights are given to foresee if people are likely to find a particular urban scene pleasant or not. Moreover, a beautiful process is done through asking participants questions, questions to improve unpleasant scenes. Using a generative adversarial network, such a class of algorithms can generate images matched to closely corresponding images of real space. Then the system can explain how the removal and the addition of urban elements can contribute to the spatial appeal. Although undeniably there are limitations of such a deep learning tool, it shows its potentiality to evaluate the public's perceptions of urban environments efficiently at scale to support urban interventions.

Fig.A.2 Interactive map of FaceLifted scenes in Boston

Source: FaceLifted, Royal society publishing
https://royalsocietypublishing.org/
doi/10.1098/rsos.190987

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