Deloitte.

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# Global artificial intelligence industry whitepaper

# Key findings:

1

**AI is growing fully commercialized, bringing profound changes in all industries.**

AI technologies have been deployed in financial, healthcare, security and a number of other areas, with widening application scenarios. The commercialization of AI is playing a positive role in accelerating business digitalization, improving industry chain structures and enhancing information use efficiency.

2

**AI has entered an age of machine learning, and the future of AI development will depend on the integration of key technologies and industries.**

Every development of AI has been associated with breakthroughs in research methods, and deep learning is one of the most important technological breakthroughs of machine learning. As AI research and application continues to expand in scope, AI will see deeper integration and application of more technologies in the future.

3

**AI investment is returning to reason, with underlying technologies and easy-to-deploy applications more favored by AI leading institutions.**

As the investment and business communities deepen their understanding of AI, the AI investment and financing market becomes more rational, with reduced frequency of investment and financing but continued increase of investment amounts. Especially after a round of competition within the industry, underlying technology companies and deployable application areas, such as startup projects in healthcare, education and autonomous driving, continue to be favored by leading AI institutions.

4

**Cities are the vehicle that carries the innovation, integration and application of AI technologies, and also the center where humans build up full sense of AI technological experience.**

Different cities perform differently in the top-level design, algorithm breakthrough, factor quality, integration quality and application quality, forming diverse and individualized AI development models.

5

**Policies and capital are driving Beijing-Tianjin-Hebei region, Yangtze River Delta and Pearl River Delta to be regions with the most AI companies, with Beijing and Shanghai taking the lead.**

For example, Shanghai put in place measures in terms of tax incentives, capital subsidies, talent attraction and government process improvement to enhance its business environment, and has attracted large amount of investment and financing capital, AI companies and talents, significantly enhancing its R&D strengths. This would also facilitate the scale up of upstream and downstream enterprises on the AI industry chain and help strengthen the city's AI industry capabilities.

6 **First tier cities represented by Shanghai and Beijing have long been leading in terms of the number of talents and enterprises, capital environment and R&D strengths.**
Beijing and Shanghai each have more than 600 AI companies, and Shanghai has established enterprise AI labs with tech giants Tencent and Microsoft, as well as AI unicorns SenseTime and Yixue Education—Squirrel AI.

7 **AI is driving the financial industry to build a broader high-performing ecosystem with enhanced business efficiency for financial enterprises and transformed enterprise process of internal operation.**
Traditional financial institutions and tech companies are working together to promote deeper penetration of AI in the financial industry, restructure services framework, increase service efficiency, and reduce financial risks while providing individualized services to long tail clients.

8 **As application of AI in education further deepens, application scenarios are shifting to cover full process of teaching.**
Among the types of AI applications in education, AI-adaptive learning is applied most widely in all the learning processes. In addition, intelligent adaptive learning system is expected to catch up from behind benefited from China's large population base, shortage in education resources and commitment to education.

9 **Digital government is mainly driven from top down achieve digitalization goals of government processes to accelerate intelligent transformation of the government.**
The needs for digital government construction vary by regions, thus enterprises require customized solutions. As the threshold for the public security sector grows higher, the strong remain strong in the sector with deepened industry convergence.

10 **The auto industry dominated by autonomous driving will see a transformation of its industry chain. The production, channels and sales models of traditional auto makers will be replaced by emerging business models.**
The boundary between rising tech companies of autonomous driving solutions and traditional auto makers will be broken. With the emergence of shared cars, shared mobility under autonomous driving will replace the concept of private cars. The development of industry norms and standards for autonomous driving will facilitate the emergence of more secure and more convenient unmanned cargo delivery and logistics.

**11** **The potential of AI application in manufacturing have been underestimated, and quality data resources are not fully utilized.**

As a highly specialized industry, manufacturing requires highly complex and customized solutions. Thus, AI technologies in this sector are mainly applied in areas that are easy to duplicate and expand, such as product quality control, sorting, and predictive maintenance. However, the massive data—reliable, stable and updated constantly—generated by production facilities has not been fully utilized. Such data could provide good examples of machine learning for AI companies to address actual problems in the manufacturing processes.

**12** **Application scenarios in retail have developed from separation to convergence, and traditional retailers are partnering with startups to build scenarios around human, goods, stores and supply chains.**

The development of AI diversifies in each retail link, and application scenarios become fragmented and enter a period with scale pilots. Traditional retailers begin to engage AI technologies, and will compete with tech giants in big data application and AI, which means retailers would be more proactive in forming partnerships with startups.

**13** **AI applications in healthcare sector are growing rapidly, but the sector needs to establish standardized mechanisms of market entry for AI products and speed up the construction of healthcare data base.**

The emergence of AI will help address the shortage and uneven allocation of medical resources as well as many other livelihood issues in the healthcare sector. However, in a strictly regulated sector that concerns people's life and health, whether AI could be applied extensively as expected will depend on the development of medical and data regulation standards.


90
74
81
87
65

# 1. New trends of AI innovation and integration

## 1.1 AI is growing fully commercialized

Now AI has entered a new stage to become fully commercialized, exerting different impacts on players of traditional industries and driving changes in the ecosystems of these industries. Such changes are mainly seen at three levels. First is enterprise change: AI is engaged in the management and production processes of the enterprise, with a trend of being increasingly commercialized, and some enterprises have realized relatively mature intelligent applications. These enterprises have been able to collect and make use of user information from multiple dimensions via various technological means and provide consumers with pertinent products and services, at the same time satisfy their potential needs through insights into development trends gained via data optimization. Second is industry change: The change brought by AI would drive fundamental changes in the relationship of upstream and downstream sectors on the traditional industry chain. The engagement of AI has expanded the types of upstream products providers, and users may also shift from individual consumers to enterprise consumers, or both, due to the change of product features. The last is labor change: The application of new technologies such as AI is enhancing the efficiency of information use and reducing the number of employees. In addition, the wider use of robots would also replace labors in repetitive tasks and increase the percentage of technological and management personnel, bringing changes in the labor structures of enterprises.

**Figure 1-1: All-round changes brought by AI**

| 1. Enterprise change | | | | | | |
|---|---|---|---|---|---|---|
| Sales | Security | Anti-fraud | HR management | Marketing | Personal assistant | Smart tools |

| 2. Industry change | | | | | |
|---|---|---|---|---|---|
| Finance | Healthcare | Education | Autonomous driving | Retail | Manufacturing |
| Digital government | Media | Legal | Agriculture | Logistics | Oil & gas |

| 3. Labor change | | | |
|---|---|---|---|
| Augmented reality | Gesture recognition | Robotics | Emotion recognition |

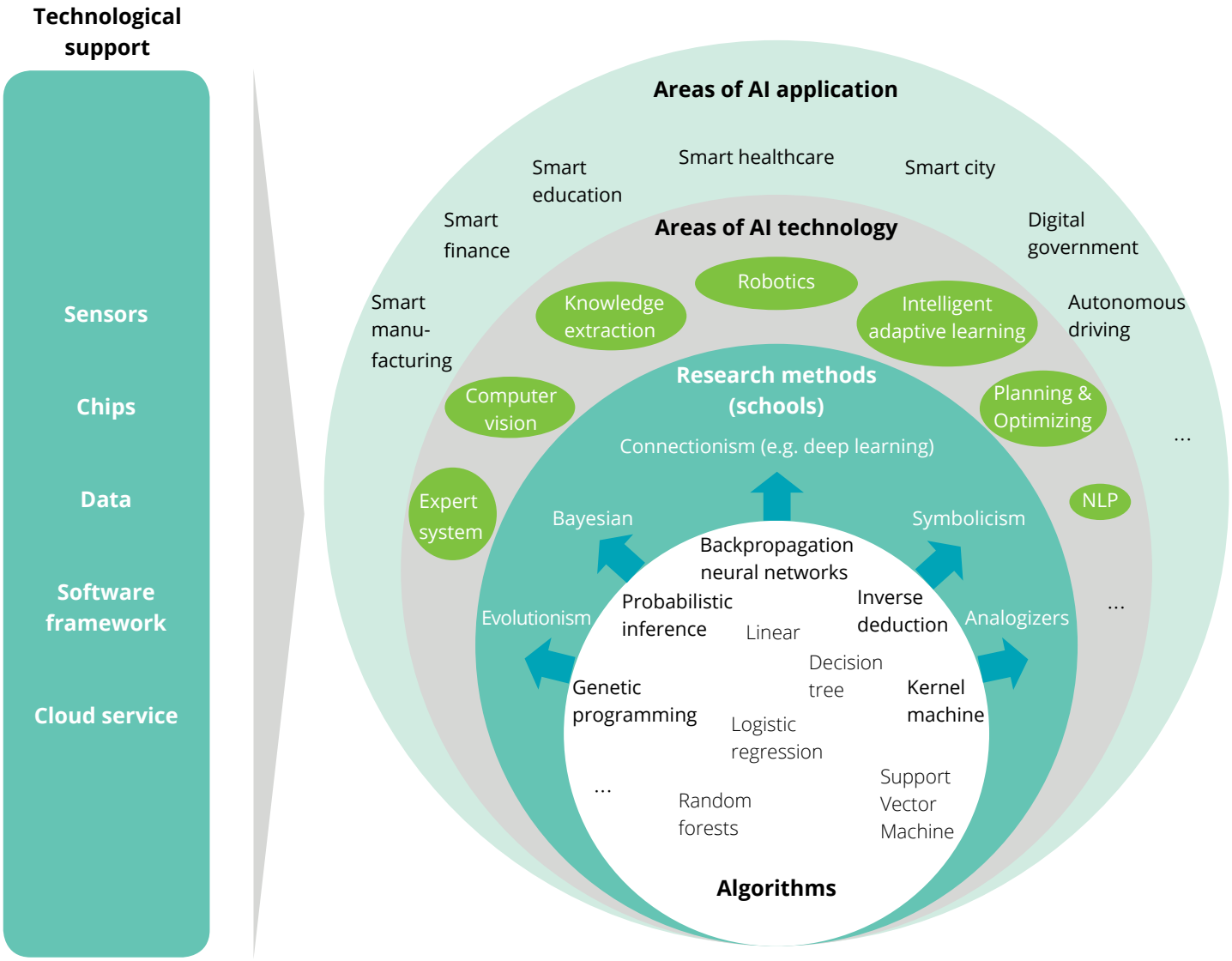
Source: Public information, Deloitte Research

## 1.2 AI has entered an era of machine learning

As technology advances and develops, the way humans learn is evolving from evolution, experience and legacy into communication and storage using computers and Internet. With the advent of computers, it has become more efficient and easier for humans to acquire knowledge. A vast majority of knowledge will be extracted and stored by machines within the near future. Computer algorithms growing more powerful would obtain human-like abilities, including vision, speaking, sense of direction, etc.

Machine learning is one of AI's core research areas among all the subfields of AI. 89% of AI patent applications and 40% of related patents within the AI realm fall in machine learning. The initial research motivation has been to equip computer systems with the human ability to learn, in order to achieve artificial intelligence. Machines find gaps in existing knowledge, then imitate human brain and simulate evolution to reduce uncertainties systemically, identify similarities between new and old knowledge, and complete learning.

**Figure 1-2: Illustration of all levels of AI**




Source: Deloitte Research

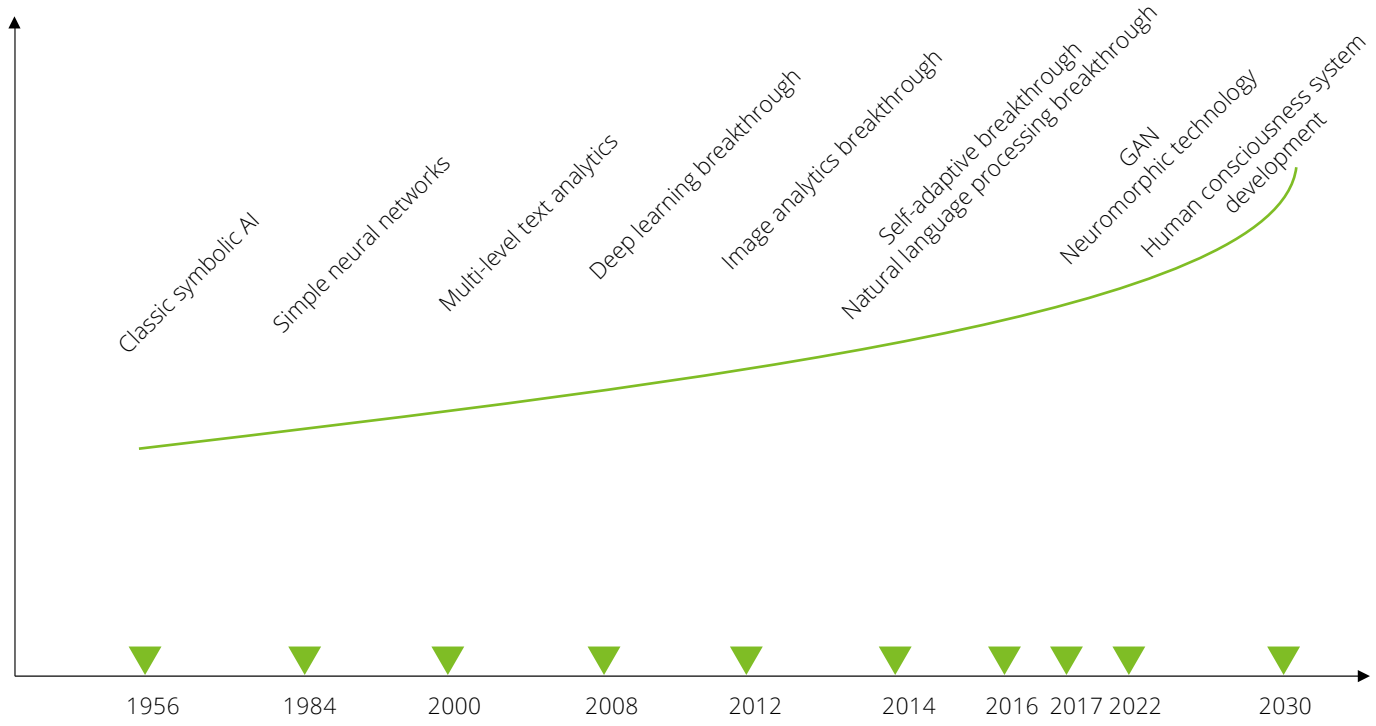
**Algorithms are the core of AI**

As the underlying logic for AI, algorithms are the direct tools that generate AI. From the course of history, we can see that AI has developed through three phases since brought up in 1956, which also reflect the alternation of algorithms and research methods. In the first phase during 1960s to 1970s, AI entered into a golden period when research methods dominated by logics became the mainstream. AI attempted to achieve machine-based logical deduction and verification, but failed at last. The period from 1970s to 1990s saw the second phase of AI development, during which immature technological capability and overpraised reputation sent it to an "AI winter" from 1974 to 1980, when research and investment in AI saw substantial declines.

From 1980 to 1987, the research method of expert system became a hot topic for AI research, re-igniting the fever of capital and researchers. During the period from 1987 to 1993, there had been significant progress in the capability of computers compared with those decades ago. People tried to create an expert system based on computers to solve problems, but could hardly build an effective system due to lack of data and constraints of experience, knowledge and rules. Capital and government support were once again pulled out, push AI into a second "winter".

The third phase was in the 1990s and after. During 1993-2011, with significantly enhanced computing power and data volume, AI technology were further improved. Till now, the surge in data volume and computing power has helped AI achieve major breakthroughs in machine learning, especially in the area of deep learning dominated by neural networks. AI's development based on deep neural network technology is now in a period of rapid growth.

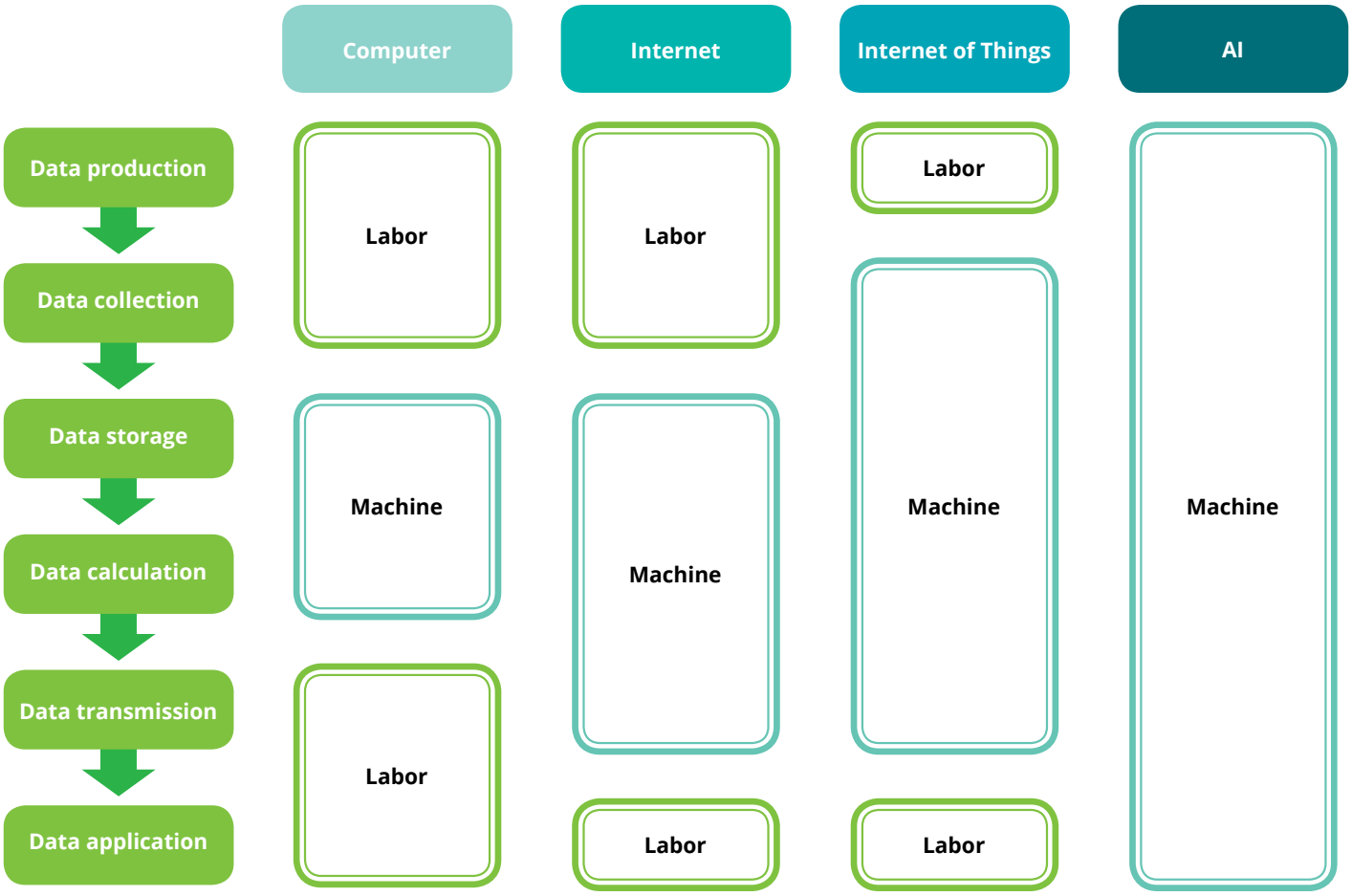
**Figure 1-3: The history of AI development**




Source: Public information, Deloitte Research

In addition, data is an essential element that underpins AI's underlying logic. Without data, data processing for AI will not be possible. With data mining's cleaning, integration, reduction and other pre-treatment means, AI could have adequate data for learning. As AI technologies iterate, the production, collection, storage, calculation, transmission and application of data will all be completed by machines.

**Figure 1-4: Development stages of data processing**

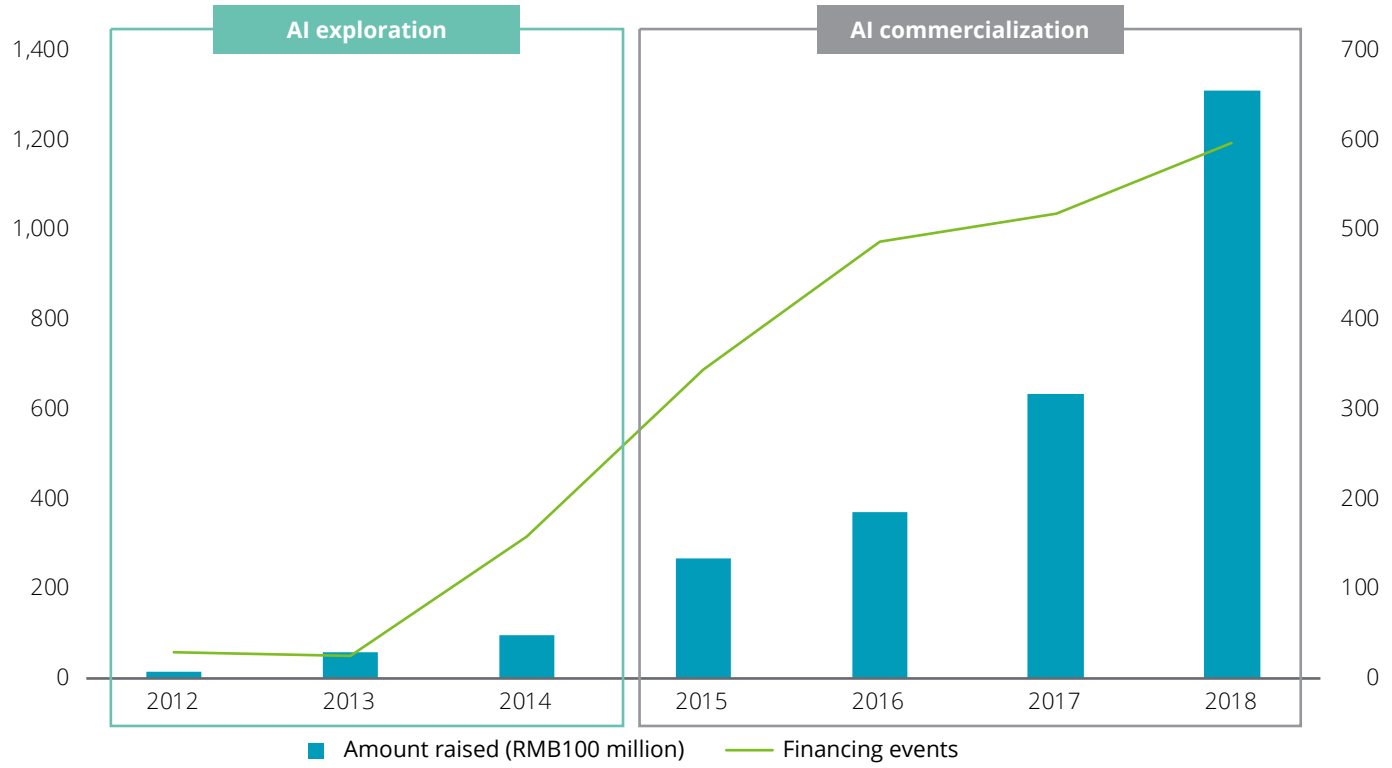



Source: Public information, Deloitte Research

### 1.3 Market investment returns to reason

From R&D and academic topic to technological startups, it only takes a few years for AI. Such shift is not only driven by people's appeals for new technologies to unleash productivity and policy support, but also powered by the capital market. As the capital market deepens its understanding of AI, market investment in AI is maturing and returning to reason. During the past five years, China's investment in AI grew rapidly, with a total investment of RMB45 billion in 2015 - the starting year of China's AI development, and investment frequency continued to increase in 2016 and 2017. The first half of 2019 has seen a total investment of over RMB47.8 billion in China's AI sector with great achievements.

**Figure 1-5: Changes of AI investment and financing**

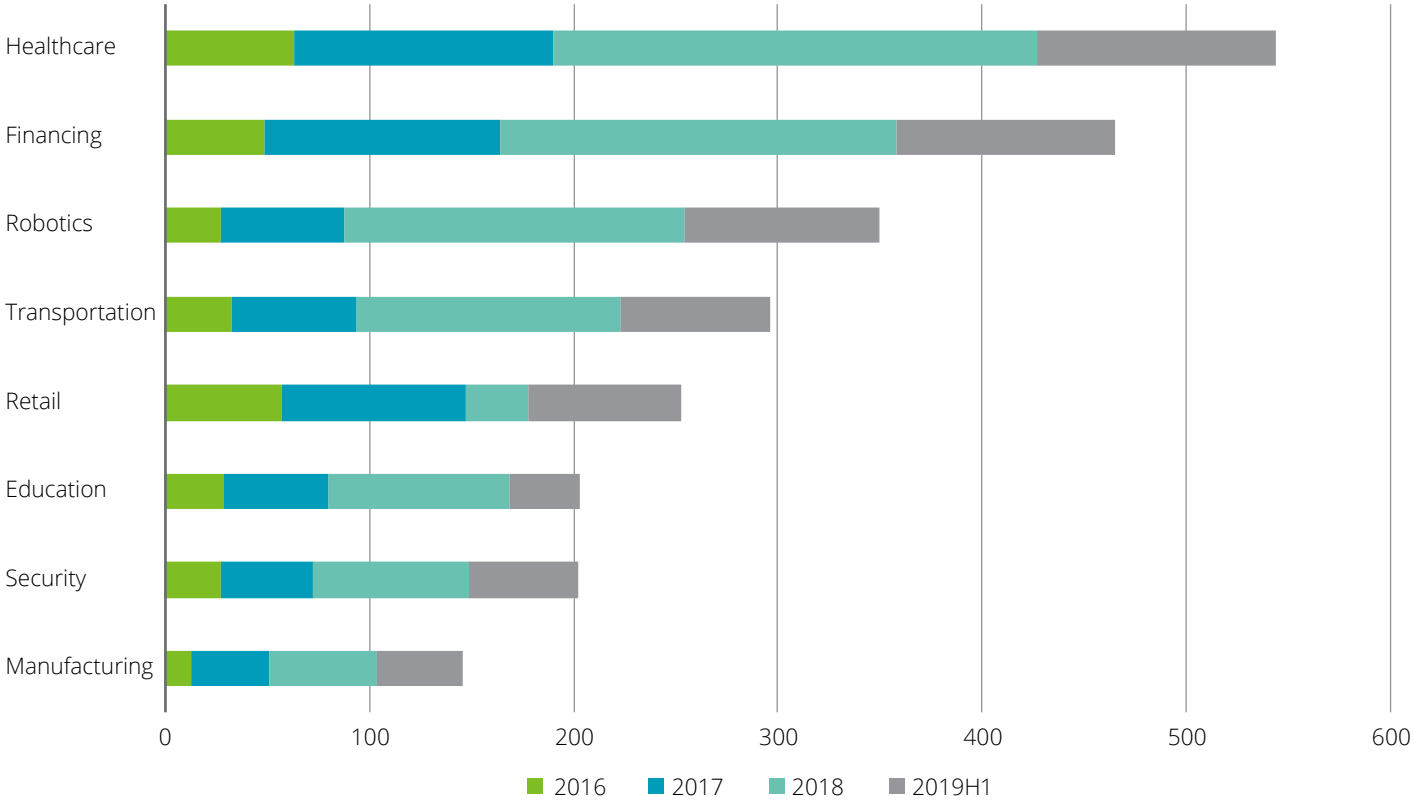



Source: Public information, Deloitte Research

We identify the following trends through our analysis of investment in AI:

- **Investors favor easy-to-deploy AI application scenarios.** Investment and financing data in recent years show that investment frequencies and amounts raised in business service, robotics, healthcare, industry solutions, basic components and finance are all higher than those in other sectors. From enterprise perspective, those with a top global team, financial strength and high-tech gene are more favored by secondary market investors. From industry perspective, however, new retail, autonomous driving, healthcare and education, all easy to deploy, indicate more opportunities, and companies engaged in such sectors could see more investment opportunities.

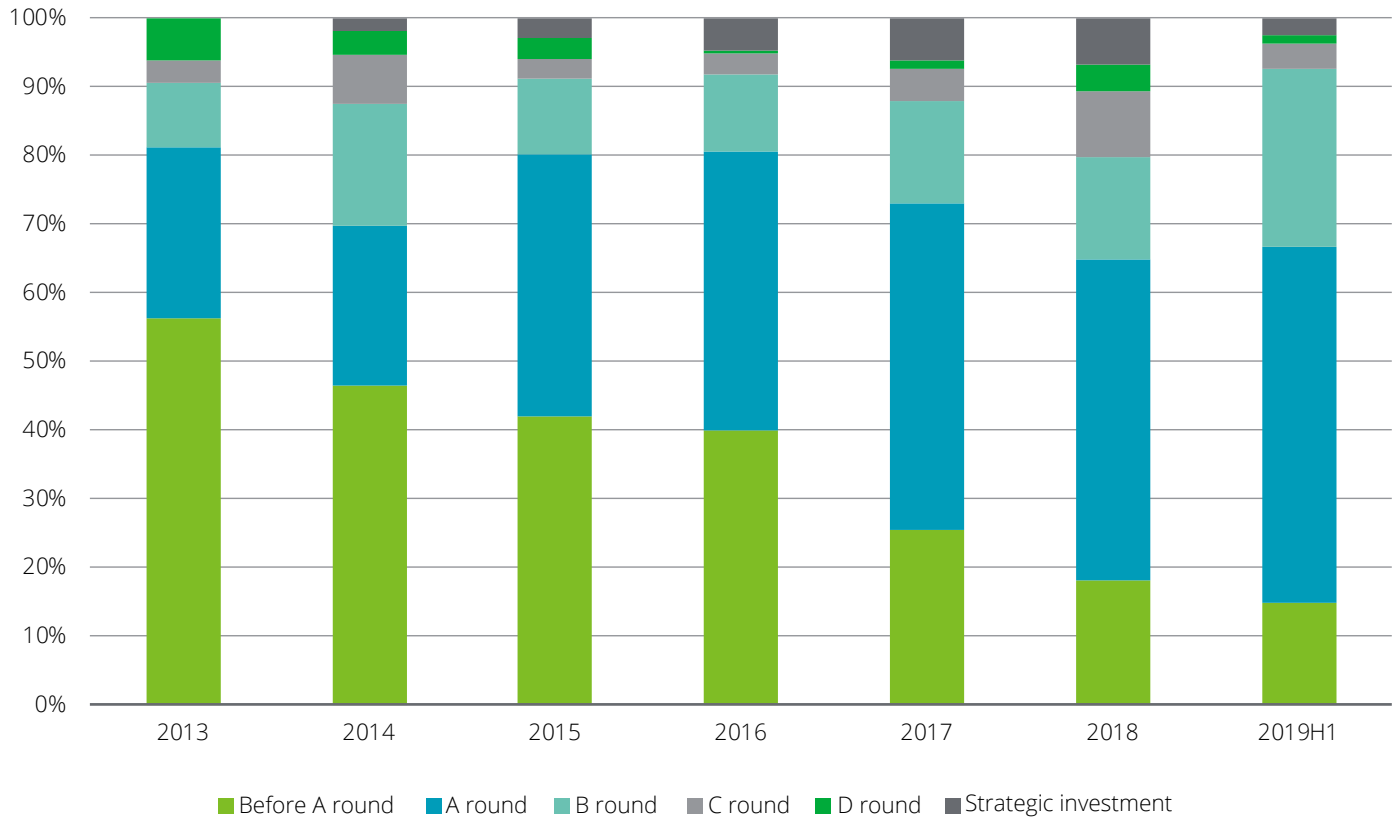
**Figure 1-6: Distribution of investment and financing frequency by AI sectors**




Source: Public information, Deloitte Research

- **Underlying technology startups become popular within the investment market.** Unlike the preference for application-oriented AI companies in earlier stage, the investment market is turning its eyes on startups engaged in AI underlying technologies. Such companies can easily become popular and are more competitive in the market with a high ceiling. As China falls behind the US in terms of development of AI underlying technologies, which are an important support for AI development, investment in underlying technologies is expected to continue growing with the advancement of AI in China.
- **The proportion of companies that complete "A" and "B" round financing remains the highest, with growing strategic investment.** More than 1,300 AI enterprises have secured venture capital investment . Though proportion of investment before "A" round is decreasing, investors remain vigorous in "A" round investment, which at present is the one with the highest investment frequency. Strategic investment started to explode in 2017. As AI market sectors grow mature, leading enterprises, mostly Internet giants, turn to strategic investment seeking for long-term partnership and development. This also suggest that strategic cooperation between AI sector and industries begin grow on capital domain.

**Figure 1-7: Rounds of investment in AI from 2013 to 2019**

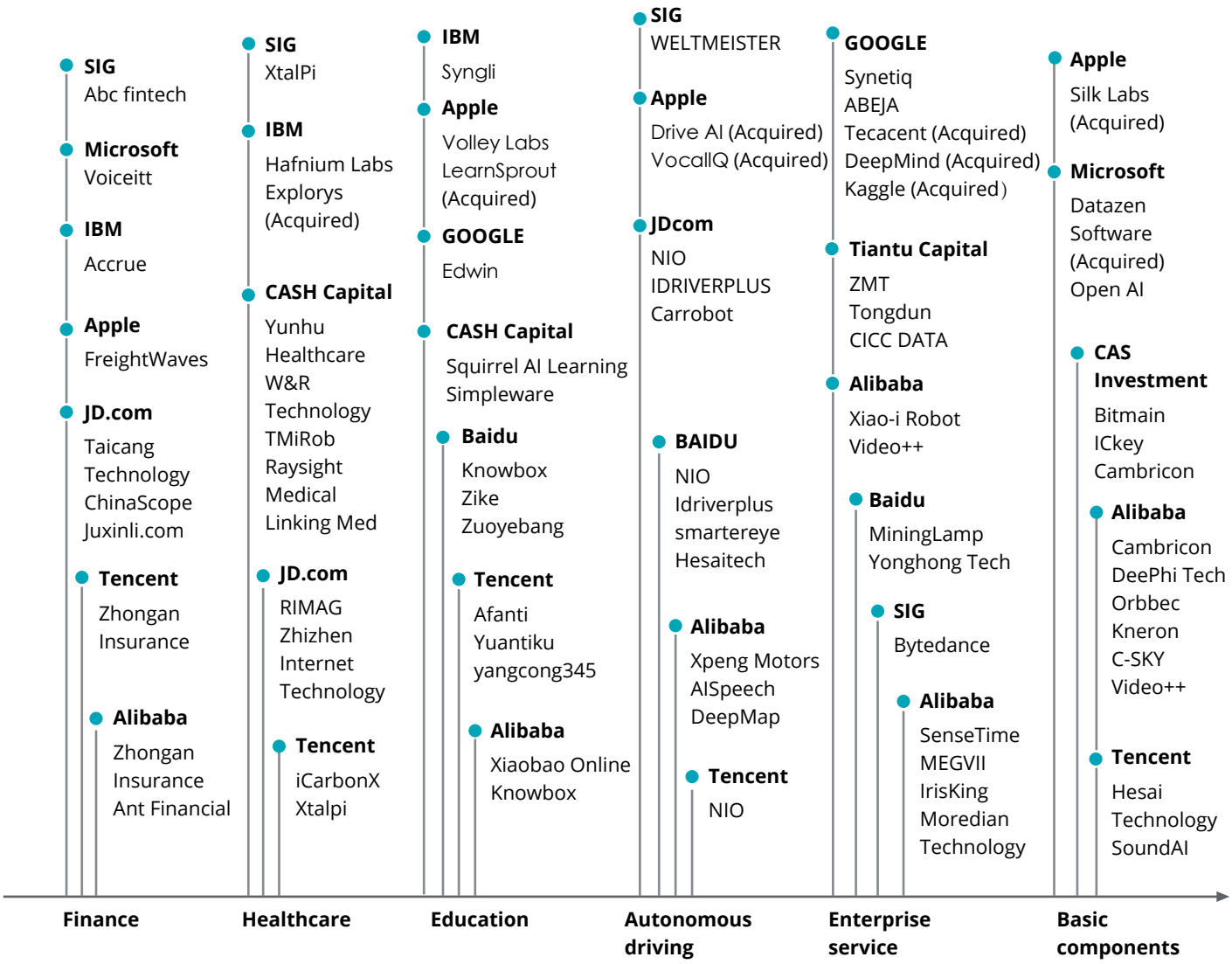



Source: Deloitte Research

- **Internet giants' AI investment links to the upstream and downstream of industries related to their businesses.** The boom of AI development also drives Internet giants with a keen sense of smell to pursue their own strategic plans. Led by Alibaba, Tencent, Baidu and JD.com, they have invested in all fields of AI sector. Projects invested by investment institutions all fall in the upstream and downstream domains of the industries in their future strategic plans, and these projects are also driving for the implementation of a national AI development strategy.

  For example, Alibaba focuses its investment in security and basic components, with major companies invested including SenseTime, MEGVII and Cambricon; Tencent mainly invests in areas such as intelligent health, education and smart car, with representative companies including NIO and iCarbonX; Baidu's investment mainly falls in auto, retail and smart home, and JD.com sees auto, finance and smart home as their priorities of investment. Companies under CAS Holdings backed by the Chinese Academy of Sciences, however, are involved in AI technological and application fields including chips, healthcare and education. As digital technologies transform and integrate in each of the industries, AI application in areas such as autonomous driving, healthcare, education, finance and smart manufacturing will be of vital importance for top enterprises.

**Figure 1-8: Major fields of investment by leading AI enterprises**




*Incomplete statistics, only include some representative companies
Source: Deloitte Research

As an emerging industry in the future, artificial intelligence companies are characterized by high growth. Thus, we screened out 50 high-growth companies based on growth rate data collected from incomplete public information and among the artificial intelligence companies in the Deloitte Technology Fast 500 list.

### Figure 1-9: Global High-growth AI Enterprises

| Ranking | Company name | Country | Growth rate | Segment |
|---|---|---|---|---|
| 1 | Shape Security | U.S.A | ~23,000%** | Business Services |
| 2 | BrainChip | U.S.A | ~16,000%** | Chip |
| 3 | Razorpay Software | India | ~11,000%** | Finance |
| 4 | BioCatch | Israel | ~10,000%** | Finance |
| 5 | Signifyd | U.S.A | ~6,000%** | Business Services |
| 6 | Yixue Education—Squirrel AI | China | ~5,000%* | Education |
| 7 | UiPath | U.S.A | ~4,000%** | Robotics |
| 8 | Remark Holdings, Inc. | U.S.A | ~3,700%** | Data Services |
| 9 | Domino Data Lab | U.S.A | ~3,200%** | Finance |
| 10 | Voltari | U.S.A | ~3,000%** | Advertisement |
| 11 | Mujin Inc | Japan | ~1,200%* | Industrial |
| 12 | Vectra AI | U.S.A | ~1,000%** | Security |
| 13 | DataRobot | U.S.A | ~900% | Deep Learning |
| 14 | Bytedance | China | ~700%* | Business Intelligent |
| 15 | Pinduoduo | China | ~650% | Retail |
| 16 | Cloudwalk | China | ~600%* | Facial Recognition |
| 17 | Welltok | U.S.A | ~500%** | Healthcare |
| 18 | Tesla | U.S.A | ~430%** | Autonomous Driving |
| 19 | SenseTime | China | ~400% | Computer Vision |
| 20 | BounceX | U.S.A | ~400%* | Marketing |
| 21 | CrowdStrike | U.S.A | ~374%* | Network Security |
| 22 | Alteryx | U.S.A | ~370%** | Data Mining |
| 23 | SequoiaDB | China | ~363%* | Finance |
| 24 | Avant | U.S.A | ~360%** | Finance |
| 25 | Cloudera, Inc. | U.S.A | ~350%** | Data Services |
| 26 | JiaHe Info | China | ~330%* | Aguriculture |
| 27 | GumGum | U.S.A | ~310%** | Computer Vision |
| 28 | Blue Prism | UK | ~304%* | Robotics |
| 29 | Unisound | China | ~300% | Speech Recognition |
| 30 | SparkCognition | U.S.A | ~260%** | Network Security |
| 31 | SmartDrive Systems | U.S.A | ~250%** | Autonomous Driving |
| 32 | HireVue | U.S.A | ~230%** | Business Services |
| 33 | Alibaba Group | China | ~225%** | Comprehensive |
| 34 | Iflytek Co.Ltd | China | ~223%** | Speech Recognition |
| 35 | Facebook | U.S.A | ~210%** | Comprehensive |
| 36 | Uber | U.S.A | ~193%* | Autonomous Driving |
| 38 | Splunk | U.S.A | ~190%** | Business Analysis |
| 37 | MEGVII | China | ~190% | Computer Vision |
| 39 | BYJU'S | India | ~184% | Education |
| 40 | ZeMoSo Technologies Pvt Ltd | India | ~170%* | Comprehensive |
| 41 | XiaoMi | China | ~162%** | IoT |
| 42 | Conversica | U.S.A | ~150%** | Marketing |
| 43 | 9FGROUP | China | ~140%* | Finance |
| 44 | Amazon | U.S.A | ~110%** | Comprehensive |
| 45 | NVIDIA | U.S.A | ~107%** | Chip |
| 46 | Globant | U.S.A | ~106%** | Data Services |
| 47 | Salesforce | U.S.A | ~90%** | Cloud computing |
| 48 | Alphabet | U.S.A | ~80%** | Comprehensive |
| 49 | Ant Financial | China | ~60% | Finance |
| 50 | Domo | U.S.A | ~40% | Business Intelligent |

Note: In the table, "~" is the estimated range; the growth rate is based on three years **, and in the absence of three years ** data, it is based on two years * and in the absence of two years * data, it is based on the year-on-year growth rate; the data are incomplete statistics, which are derived from published public data and private databases, and do not guarantee the accuracy and timeliness of the data.

### 1.4 Cities become the main battleground for AI innovation, integration and application

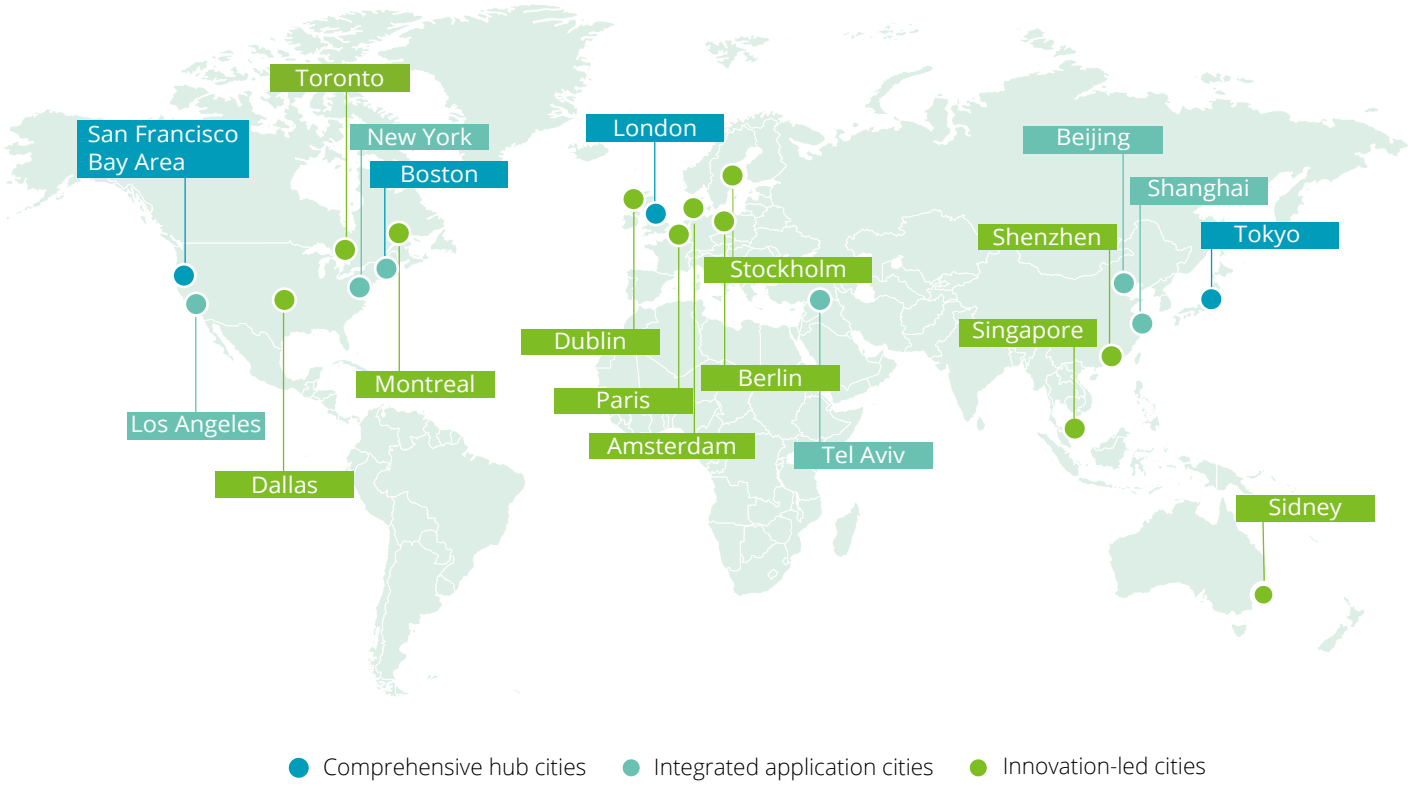
Cities serve as the vehicle that carries the innovation, integration and application of AI technologies, and also the center where humans build up full sense of AI technological experience. Over the past few years, major cities around the world have played various roles in driving the development of AI technologies, established their own ecosystems, and achieved initial success in empowering industry applications and facilitating regional economic development, raising thoughts, perception and actions on the new round of industrial revolution. With AI applications being deployed at city level, cities become the main battleground for AI innovation, integration and application.

Though with varied key success factors of AI, cities across the world in general have built up development ecosystems that facilitate integration of technologies and the city. Through continuous monitoring of more than 50 AI application segments, over 100 AI related universities and research institutions, over 200 top enterprises, more than 500 investment entities, 7,000 AI companies and over 100,000 key AI talents, we have outlined the characteristics, framework and development path of AI technologies and industry ecosystems centered on cities. Considering the factors in overall, we believe that the degree of innovation and integration of AI technologies in a city can be measured via the following five aspects:

- **Top-level design,** including AI industry supporting policies, special legislations, open data policy and the level of openness, etc.
- **Algorithm breakthrough,** including core R&D links of key AI software and hardware, such as AI chips
- **Factor quality,** including AI leading figures, capital support, pay level of scientists, influence of industry conferences, etc.
- **Integration quality,** including connectedness of frontier disciplines (AI: +Cloud、+Blockchain、+IoT、+5G、+Quantum Computing and other frontier technologies), diversity of innovation entities (top enterprises, academic institutions, etc.), cultural diversity, etc.
- **Application quality,** including finance, education, healthcare, digital government, autonomous driving, retail, manufacturing, integrated vehicle development, etc.

Based on the performance of cities globally in terms of the above five indicators, Deloitte has selected a total of 20 representative cities of AI innovation, integration and application from three categories:

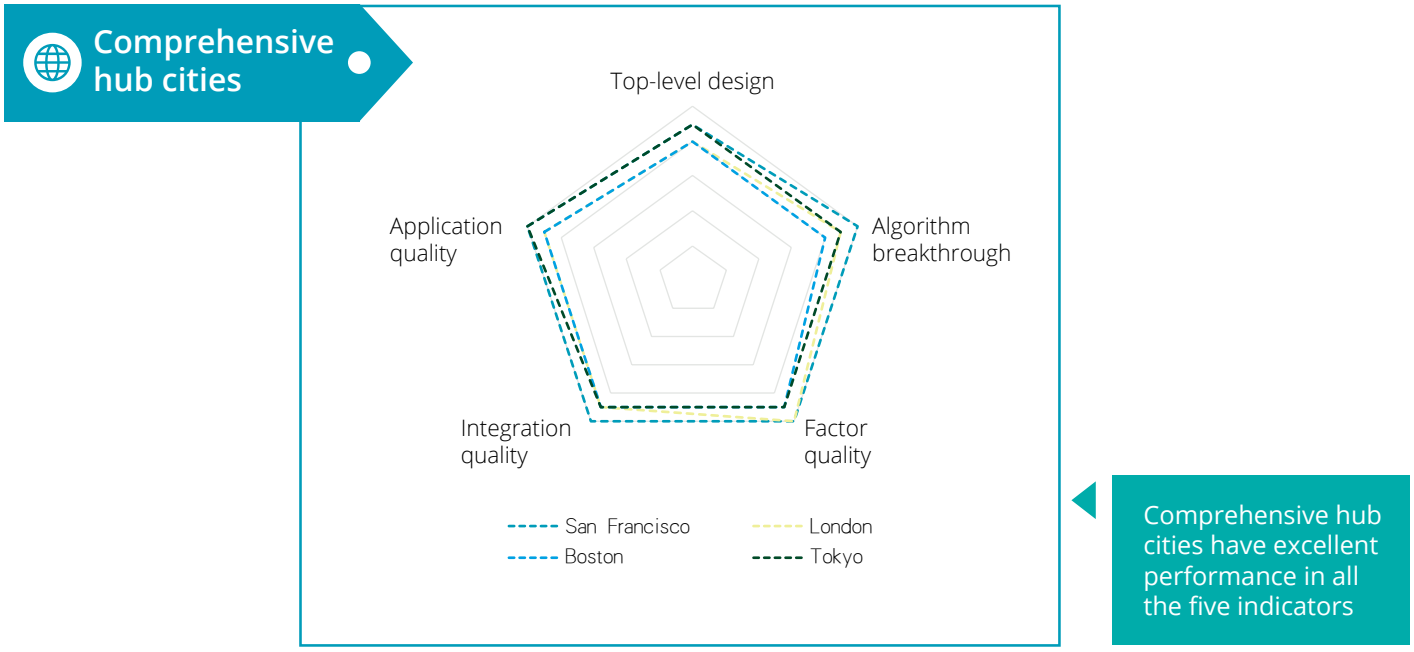
**Figure 1-10: 20 global cities of AI innovation, integration and application in 2019**




Source: Deloitte Research

## Comprehensive hub cities

**Figure 1-11: Comprehensive hub cities**




Source: Deloitte Research

### San Francisco Bay Area

As a region known globally for AI innovation, San Francisco Bay Area performs well in all the five indicators of AI innovation, integration and application. For factor quality, San Francisco Bay Area is a center of global AI capital. Data shows that the region attracted 38% of AI investment globally during 2000-2016, and over one third of AI companies in the US have grown out of this region[1] . Moreover, San Francisco Bay Area has also actively hosted the AI forum with global impact - 2018 AAAI Conference - to further enhance its influence in AI development. In terms of integration quality, San Francisco Bay Area is home to Stanford, Berkeley, San Diego and a number of other top research universities, and has transferred lots of AI talents to tech giants including Facebook, LinkedIn, Amazon, Apple, and Google. It should be noted that[2] the above companies offer an average annual pay of up to USD293,000 for machine learning scientists, which is highly attractive for the concentration of AI talents. As to application quality, the Silicon Valley serves as the core carrier of AI industry for the region, and has attracted IBM, Google, NVIDIA, Intel and many other leading tech companies to actively expand their operations in different fields of application including smart home, smart transportation, smart healthcare, smart retail, smart energy and smart water resources.

1. *Global AI Development Report 2017*, Wuzhen Institute
2. Qianzhan Research Institute

**London**

London has always been standing at the forefront of AI industry innovation as an AI hub with the highest density of innovation in Europe. For application quality, AI star company DeepMind, headquartered in London, developed a Go game robot AlphaGo that defeated the world's No.1 Go champion Ke Jie, which was a milestone in AI's development. Now DeepMind has partnered with UK's medial institutions and electrical energy authority to develop solutions that apply AI in healthcare, power and other sectors, in order to enhance disease control and energy use efficiency. In terms of integration quality, London is the locomotive of AI financing and investment in Europe. Data shows that UK's aggregated funds raised for AI accounted for 49% of that in Europe during 2000-2006, of which more than 60% concentrated in London[3]. According to statistics, UK's AI companies have raised up to USD1.251 billion with 145 rounds of financing, an average of USD 8.6276 million for each round[4]. As to talent, a great number of AI talents from top schools such as Cambridge, Oxford and King's College have significant promoted the development of cloud computing and AI hardware in London. For example, the well-known semi-conductor company ARM was separated from Cambridge.

**Boston**

The birthplace of AI, Boston has huge influence both in the academic and the business communities. From perspective of factor quality, Boston is the host of the world-class AI World Conference & Expo, and John McCarthy, father of AI, and Marvin Lee Minsky have emerged from Boston's academia, who first came up with the concept of "artificial intelligence" at the Dartmouth Conference and was granted the Turing Award for their outstanding contribution in AI sector. In terms of integration quality, Boston houses a number of world-class universities, with a total of 35 universities including Harvard, Boston University, UMASS and MIT continuously providing high-end talents for the development of AI in the region. In addition, as indicated by MIT, Boston also has many top-notch AI research institutions, including the world's largest campus lab – MIT's Computer Science and Artificial Intelligence Laboratory and the MIT-IBM Watson AI Lab set up by IBM with an investment of USD240 million. As to application quality, Boston takes the lead in AI application in robotics and bioscience benefited from the region's accumulated research experience in the two fields. According to Emerj Artificial Intelligence Research, more than 90% of land mobile robots used by the US military are developed in Boston.

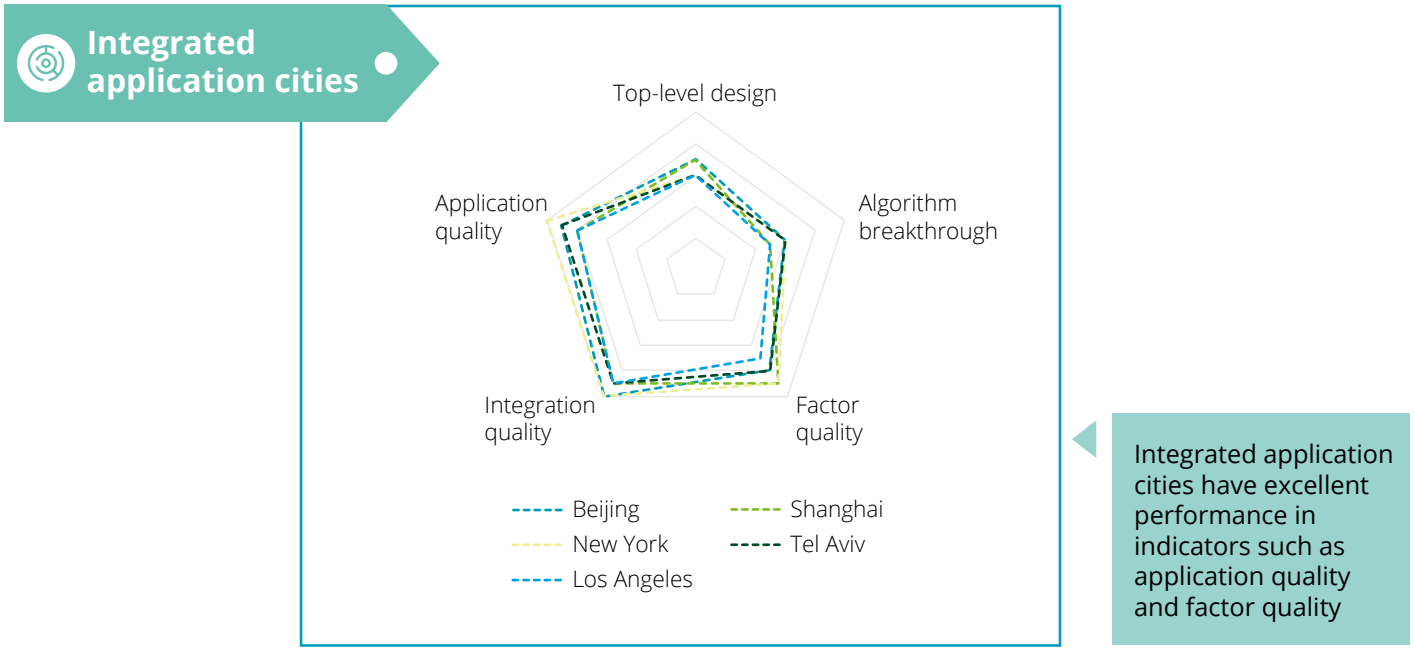
**Tokyo**

Tokyo is the capital city of AI industry in Japan. In terms of top-level design, the Japanese government set up an "AI Strategy Council" to promote the development of AI in Tokyo, and has developed various policies encouraging enterprises to develop AI. As to application quality, Tokyo tends to develop towards autonomous driving and robotics. Honda has established its AI research base in Tokyo in recent years, with a focus on enhancing its competitiveness in autonomous cars, while Yaskawa is the most representative company in robotics, whose industrial robots have been deployed to conduct assembly and welding tasks in auto, machinery and other areas. As to factor quality, Tokyo has been active in hosting AI EXPO, an international AI exhibition that gathers industry leaders including Alibaba, Salesforce and FujiSoft. With regard to integration quality, the Japanese government has built a number of AI research institutions, including the Artificial Intelligence Research Center (AIRC) and the Center for Advanced Intelligence Project, and more than 20 universities such as the University of Tokyo, Osaka University and Waseda University has also set up AI-related disciplines, laying a solid foundation for the development of AI.

3. *Global AI Development Report 2017*, Wuzhen Institute
4. *Global AI Development Report 2018*, Wuzhen Institute

## Integrated application cities

**Figure 1-12: Integrated application cities**




Source: Deloitte Research

### New York

As a financial and technological center in the US, New York performs especially well in AI's integration quality and application quality. With regard to integration quality, New York's good investment environment and open channels of financing has provided essential support for the development of AI startups. Based on the reported published by New York State, New York City has a total of 7,600 tech companies in 2016, an increase of 23% compared with that in 2010. In addition to the tech giants from Silicon Valley, there are also a great number of tech "unicorns" with a market value exceeding USD1 billion, including Warby Parker, Blue Apron, Buzzfeed, FanDuel, OscarHealth and ZocDoc, creating a strong atmosphere for enterprise innovation. In terms of application quality, New York is the leader of smart city development in the US. The New York government has cooperated with Cisco and IBSG to launch the Smart Screen City 24/7 program, aiming to convert its traditional telephone booths into smart screens with touch, audio and video features, which provide information inquiry service to citizens and serve as WiFi hot spots to build the largest urban WiFi network in the US. In addition, New York has also constructed a commercial and residential region in Manhattan West, and installed large number of electronic detectors utilizing digital technologies to monitor transportation, energy and air quality in real-time within the region. At the same time, as the world's financial capital, New York has also pursued a unique path for the development of Fintech. Many famous global financial institutions, including Citibank, J.P. Morgan and Morgan Stanley, has launched their financial service products targeting at financial scenarios such as smart investment advisory and smart credit.

### Shanghai

As the leader of China's economic development, Shanghai has been striving to deepen its AI innovation, integration and application, working to build a "Shanghai highland" of AI. With regard to top-level design, Shanghai continues to improve and refine its development strategy and policies in the AI sector. Following the Opinions on *Promoting the City's Next Generation of AI Development*, Shanghai published the *Implementation Measures on Speeding Up High Quality AI Development in Shanghai* at the World AI Conference in September 2018. The Measures put forward 22 specific policies on the building of AI talent pool, sharing and application of data resources, industrial distribution and cluster, introduction of government funds and support, etc. As to integration quality, as a world-renowned financial center, Shanghai has become the core region driving the setup and operation of AI industry investment funds. From the perspective of investment projects, Shanghai has an optimal investment environment with spatial carriers focusing on incubating AI innovations, where projects launched cover healthcare, education, big data and other popular fields. At present, Shanghai is home to nearly 400 core AI companies, and has launched several basic research platforms including the Microsoft-INESA AI Innovation Center and the Shanghai Brain Science and Brain-Inspired Intelligence Research Center. The city has also attracted Amazon, Baidu, Alibaba, Tencent, iFLYTEK and other industry innovation centers and AI labs. In terms of application quality, Shanghai as the first national pilot zone for AI innovation and application focuses on developing autonomous driving, AI + 5G, smart robots, AI + education, AI + healthcare, AI + industrials and other application scenarios. For example, Tesla is building a super factory in Shanghai which will fully deploy smart and automated production technologies. Moreover, Shanghai is actively working to construct the Maqiao Artificial Intelligence Innovation Experimental Zone, with an aim to build a model for the future deployment of AI scenarios in Shanghai.

### Beijing

As China's political and economic center, Beijing is playing a key role in the innovation, integration and application of AI technologies in China. In terms of top-level design, Beijing has introduced several policies to accelerate the growth of AI industry since 2016, including Measures on Promoting the Innovation and Development of Intelligent Robot Industry in Zhongguancun and Guiding Opinions on Accelerating the Development of AI Industry, aligning with the country's planning objectives and putting it ahead of other cities. In terms of integration quality, top research institutions, including Tsinghua University, Beihang University and Peking University, provide a large number of talents for Beijing's AI industry. The effect of talent aggregation in the capital makes Beijing an attractive cluster of 43% of Chinese AI startups and AI research centers of domestic and foreign tech giants, such as Google Beijing AI center, Baidu's National Engineering Laboratory for Deep Learning Technology and Applications. Regarding application quality, at the meeting of promoting the building of application scenarios in Beijing held in June 2019, Beijing Municipal Science & Technology Commission released the first list of ten application scenarios and decided to invest RMB3 billion in city construction and administration and people's livelihood improvement, creating application scenarios based on AI, Internet of Things (IoT) and big data in order to enhance the city's lean management capability and public security. In application scenarios for self-driving, Beijing has issued a self-driving testing license to Baidu and provided testing venues.

### Tel Aviv

AI innovation is deeply rooted in the DNA of Tel Aviv, Israel, empowering the city to take lead in the quality of factor, integration and application around the world. Regarding factor quality, AI startups in Tel Aviv maintain high-level volumes of financing and continue to grow. According to a report released by a non-profit organization Start-Up Nation Central, Israel's AI startups raised USD2.25 billion in 2018[5] . With regard to integration quality, Israel has 1,150 AI startups[6] covering machine learning, deep learning, computer vision and NLP. Besides, Israel also has several top research-oriented universities including the Hebrew University of Jerusalem, Israel Institute of Technology and Tel Aviv University. In respect of application quality, Tel Aviv-based AI companies are engaged in several service areas oriented on companies and consumers, involving social media, e-commerce, agriculture, oil, natural gas, mining and manufacturing. Take the application in social media as an example. Cyabra helps social media companies identify and forecast fake social media accounts with technologies including user profile and corpus for sentiment analysis.

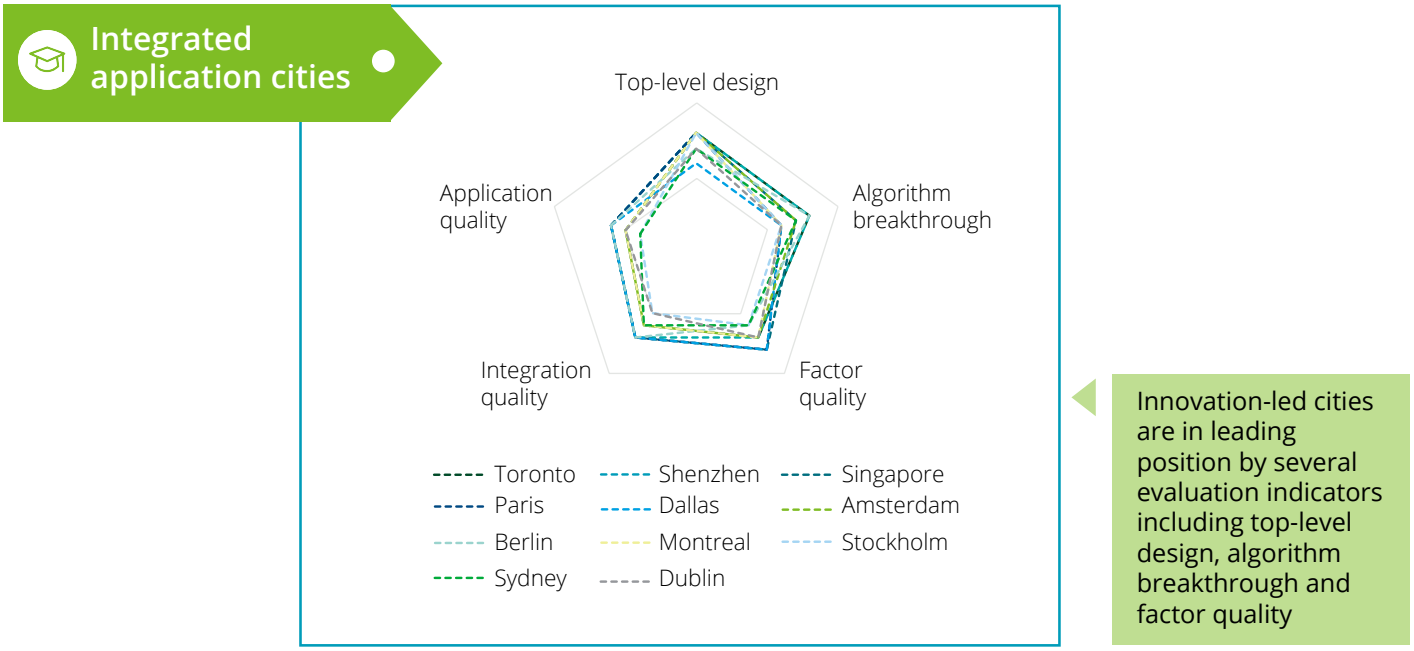
### Los Angeles

Los Angeles, another key city of AI in the United States, is prominent in top-level design and the quality of factor and application. Regarding top-level design, the United States introduced the National Artificial Intelligence Research and Development Strategic Plan to develop public datasets for AI training and evaluate AI technologies. In terms of factor quality, Los Angeles has organized a series of high level AI conferences including the United States AI summit, Los Angeles Forum for Big Data & Artificial Intelligence and Southern California AI & Data Science Conference which attracted many established AI institutions, including Salesforce, IBM, Redis Lab, Microsoft and Uber to release their industry reports at the 2018 conference. In terms of application quality, Los Angeles has successfully applied AI in smart transportation, smart healthcare, digital governance and digital security. The application of AI in transportation as an example, by creating an automated transportation monitoring system composed of a set of road sensors, hundreds of cameras and 4,500 systematically controlled traffic lights, the city has reduced the traffic flow by 12% and improved the vehicle speed by 16%[7] .

5. Source: Start-Up Nation Central
6. Source: Start-Up Nation Central
7. Source: Smart City Council

## Integrated application cities

**Figure 1-13: Innovation-led cities**




Source: Deloitte Research

**Toronto**

As one of three AI hubs implementing the Pan-Canadian Artificial Intelligence Strategy developed by the Canadian government, Toronto is a global model city in driving AI innovation. In terms of top-level design, the flexible and friendly environment makes Toronto attractive to large numbers of AI researchers and engineers and significantly boosts the growth of local AI industry compared to increasingly strict immigration policies of the United States. Regarding factor quality, local strong investors, incubators and technical experts and leaders in Toronto's AI industry, such as Geoffrey Hinton, are actively contributing to the development of Toronto's AI industry. In respect of integration quality, two world-leading academic institutions, University of Toronto and University of Waterloo are educating core AI industry talents including engineers, developers, computer specialists and data scientists for Toronto every year. Besides, Mars Discovery District, one of the world's largest innovation centers located in Toronto, Vector Institute from University of Toronto and a non-profit organization Creative Destruction Lab are making concerted efforts to gather local technical and commercial talents together to drive AI innovations in the city. In terms of application quality, Toronto focuses on developing application scenarios of AI in healthcare, finance, biopharmaceutical industry and e-commerce and building AI-powered communities. In biopharmaceutical industry, for example, Toronto's AI company Cyclica successfully developed a new type biological big data and AI platform that is used in developing better drugs in the pharmaceutical industry.

### Shenzhen

Shenzhen, one high-tech center in China, has 20% of Chinese AI companies with extensive industry experience in manufacturing and hardware. In terms of algorithm breakthrough, Shenzhen has developed a world-class internet giant Tencent and a world-renowned mobile device provider Huawei in the past decades. Besides, a batch of AI algorithm and software and hardware startups, including MEGVII, YITU, SenseTime, UBTECH and iCarbonX, set up offices in the city. In fact, as a concentration of AI talents in Southern China, Shenzhen attracts a great deal of talents from top universities such as Sun Yat-sen University, South China University of Technology and Jinan University to provide steady talent reserves for the growth of all parts in local AI industrial chain. In respect of application quality, Shenzhen is a real tech industry tycoon by contributing the most of AI patents in China. Shenzhen is leading in industrial robots, civilian drones and smartphones in China while many new industries and business formats are emerging, such as smart manufacturing, smart healthcare, smart home and agriculture.

### Singapore

Singapore is a typical country where the AI industry is developed both by public and private sectors. In terms of top-level design, the government is actively leading the growth of AI industry by introducing traffic regulations on autonomous driving vehicles in 2018 to drive investment in the application scenario. Moreover, the government of Singapore worked with the World Economic Forum in building the first governance framework on ethical use of AI to drive companies and the society to consider relevant issues. Regarding factor quality, the Singapore government released the plan of AI.SG in recent years. According to the National Research Foundation (NRF), the NRF and other public agencies and private companies will invest SGD150 million in developing AI industry. In respect of integration quality, several giants including SAP and Salesforce set up AI research centers to provide abundant resources for local AI industry. The country also has several excellent industry leaders, including scientific talents, such as Professor Steven Hoi who released over 200 research papers in top-level industry conferences and magazines. In terms of application quality, Singapore focuses on the AI application scenarios covering healthcare, transportation, finance and commercial services and manufacturing to empower local economy.

### Paris

As one of the most attractive AI hubs for investment in Europe, Paris has strengths in top-level design, the quality of factor and integration. In terms of top-level design, the release of France's Artificial Intelligence Strategy prioritizes AI as France's national strategy. And the country plans to build public bodies and private data sharing platforms to improve the data sharing. With regard to factor quality, the French government plans to invest EUR1.5 billion to support research and innovation in the field[8] . Besides, the government of Paris Region also provides financial supports for AI start-ups. Regarding integration quality, some leading companies, such as IBM, Google, Samsung and Facebook, set up their AI headquarters in Paris. A number of top labs, over 1,000 AI startups and world-renowned research universities including University of Paris 1 Pantheon-Sorbonne enable Paris to be a thriving AI innovation base and ecosystem.

### Dallas

Dallas, one of model AI cities in the United States, is leading in the quality of factor, integration and application. In terms of factor quality, Professor Vibhav Gogate, one leading figure in Dallas's AI industry, won CAREER award granted by the National Science Foundation and received USD1.8 million research funding[9] provided by the Defense Advanced Research Projects Agency. The Big Data & AI Conference held in early 2019 attracted many AI industry leaders to attend, including Google, Amazon, Oracle, IBM and Verizon. Regarding integration quality, the University of Texas at Dallas provides top AI research talents and its computer science ranks sixth in the world in AI and NLP sectors[10] . The university published a series of research reports at the International Joint Conference on Artificial Intelligence. In respect of application quality, Dallas stands out in the application of AI in retailing. An AI start-up Symphony Retail AI, one of industry leaders in Dallas, won the "Best Use of AI in Retail" award granted by Awards.AI, the world's biggest global annual achievement awards for artificial intelligence.

8. *Le Figaro*, France
9. Official website of the University of Texas at Dallas
10. Official website of the University of Texas at Dallas

### Amsterdam

Amsterdam is growing to be an important AI city in Europe with a leading position in algorithm breakthrough and the quality of factor and application. In terms of algorithm breakthrough, Amsterdam has achieved certain milestones in core technical areas in computational intelligence, sensing intelligence and cognitive computing. Regarding factor quality, the Netherlands International Artificial Intelligence Exhibition and International Internet of Things Exhibition are the biggest AI industry events in Europe. The event held in the RAI International Exhibition and Congress Centre in June 2018 attracted numerous world-renowned AI institutions and experts from IBM, DHL and KLM. In terms of application quality, a host of Netherlandish AI startups are established in Amsterdam mainly engaged in financial services, retailing, healthcare, manufacturing, real estate, media and agriculture. For example, the machine learning model and visual systems that can adapt to existing systems provided by the enterprise BI platform Pyramid Analytics are applied by many industry clients, e.g. Siemens.

### Berlin

Berlin is the strongest city in AI basic research in Germany with outstanding performance in algorithm breakthrough and the quality of integration and application. In terms of algorithm breakthrough, Berlin has the world's largest non-profit AI research institution German Research Center for Artificial Intelligence (DKFI) whose shareholders include global tech giants such as Google, Intel, Microsoft, BMW and SAP. Besides, a world renowned non-profit research institution Max Planck Institute is also located in Berlin, which owns over 80 research institutes[11] . All these equip Berlin with world leading strengths in basic research. Regarding integration quality, the cluster gathering large numbers of AI talents, 40.2% of German AI startups[12] and research institutions makes Berlin a diversified environment for integration and innovation. In respect of application quality, Berlin is internationally competitive in drone sector. For example, German carmakers, e.g. Audi, are leading the world in the application of AI technologies.

### Montreal

Montreal is an emerging AI center dubbed as the "New Silicon Valley" in AI, with a strong lead in the top-level design and the quality of factor and integration. In terms of top-level design, the Quebec provincial government introduced a series of incentives including tax incentives, favorable policies, and investment and loan incentives to attract many AI companies to settle into the city. Regarding factor quality, the government provides funding supports for Montreal to develop its AI industry. The Quebec provincial government will invest CAD330 million over the next five years in AI industry, of which about CAD38 million will be used for attracting AI talents and CAD65 million for the application of AI[13] . The innovative research in AI developed by Yoshua Bengio, one AI leader in Montreal, attracts research funding from several high-tech giants including Facebook, Microsoft and Google.

11. Official website of Max Planck Institute
12. *Handelsblatt*, Germany
13. 2019 Quebec provincial budget

Besides, the Conference and Workshop on Neural Information Processing Systems (NIPS), a top-level AI conference with international influence was also founded in Canada. In respect of integration quality, some international AI giants, e.g. Google, Facebook, Samsung, set up their research centers in Montreal where also locate many AI research institutions such as algorithm study AI labs (MILA), AI labs (IVADO), McGill University and the University of Montreal.

**Stockholm**

Stockholm is a leading AI city in Northern Europe with strengths in the top-level design and factor quality. In terms of top-level design, the Swedish government has defined AI and machine learning as a priority area that is able to strengthen Swedish competitiveness and welfare. Sweden is one of the 25 European countries who signed the Declaration on Cooperation on Artificial Intelligence and also one of eight Nordic and Baltic countries who signed the Reinforcement of Declaration of Cooperation on Artificial Intelligence in Stockholm, including Denmark and Finland, to drive the growth of AI through national strategies. With regard to factor quality, Stockholm has held several international AI conference, including International Joint Conference on Artificial Intelligence (IJCAI), European Conference on Artificial Intelligence (ECAI), International Conference on Machine Learning (ICML) and Nordic Business Forum, covering machine learning, computer vision, multi-entity system and NLP.

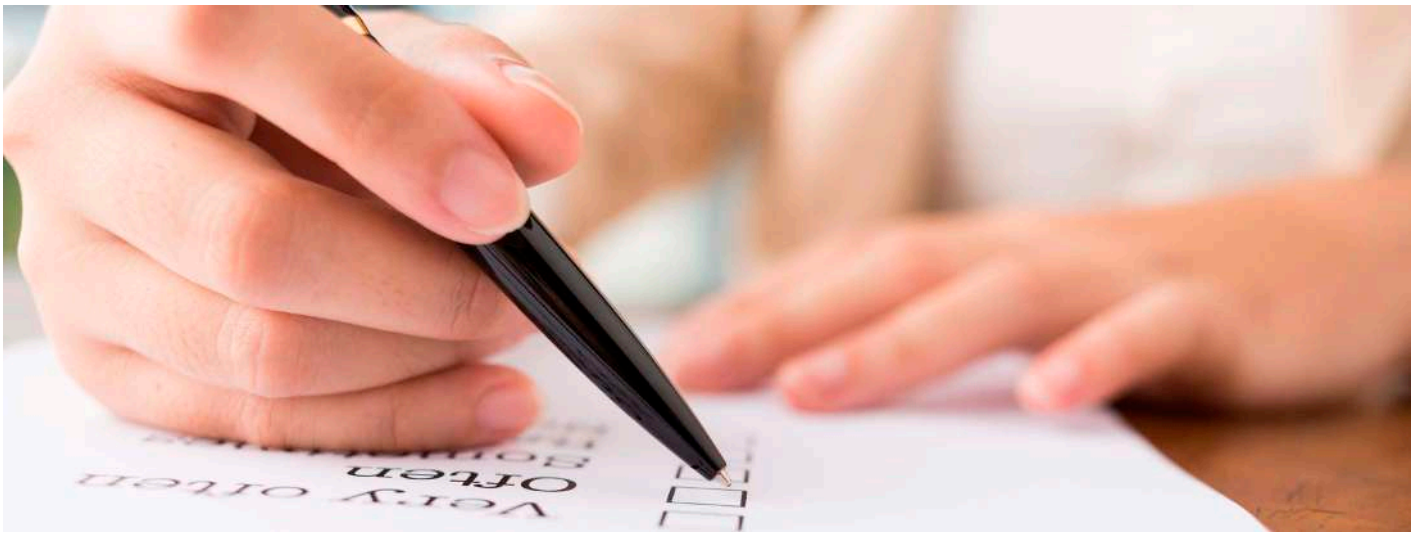
**Sydney**

Sydney is a world-renowned AI center, it has made outstanding achievements in algorithm breakthrough, factor quality and integration quality. In terms of algorithm breakthrough, Dr. Ross Quinlan from Sydney University invents the world's best AI data mining algorithm C4.5, demonstrating Sydney's advantage in data mining algorithm. As for factor quality, Sydney has several leading AI talents. For example, Tao Dacheng, computer science professor from Sydney University, is a member of the American Association for the Advancement of Science (AAAS), which is the highest honor in computer vision, deep learning and data learning sectors. Besides, the Australian government also allocates USD250 million to support AI related CRCs[14] . Regarding integration quality, Sydney University has established the UBTECH Sydney Artificial Intelligence Centre and the University of Technology Sydney has the Sydney Centre for Artificial Intelligence (CAI). UBTECH Sydney Artificial Intelligence Centre teams up with Dell EMC on AI and robot application research; CAI has published over 740 papers related with AI, among them, 337 articles have been published by industry leading journals[15] .

**Dublin**

Dublin, the capital and the largest city of Ireland, is holding a leading position in top-level design, factor quality and integration quality. In the aspect of top-level design, the Investment and Development Agency (IDA) and Enterprise Ireland develop an AI island plan with joint efforts, which rolls out postmaster program led by industry experts and relevant short-term education courses, to increase AI talents in Ireland. In terms of factor quality, Dublin's AI industry has enough financial support. AI startups have attracted more than EUR5.8 billion investment.[16] On the integration quality, Dublin has built complete ecosystem for AI startups by attracting tech giants such as Facebook, Google and Microsoft. Moreover, many tech companies are interested in setting their AI research centers in Dublin, including the EUR4-million cooperation project between Samsung and University College Dublin[17] and EUR17.7-million project between Huawei and Trinity College Dublin[18] .

14. Department of Industry, Innovation and Science of Australia
15. Official website of University of Technology Sydney (UTS)
16. Tech Ireland
17. Official website of University College Dublin
18. Official website of Trinity College Dublin



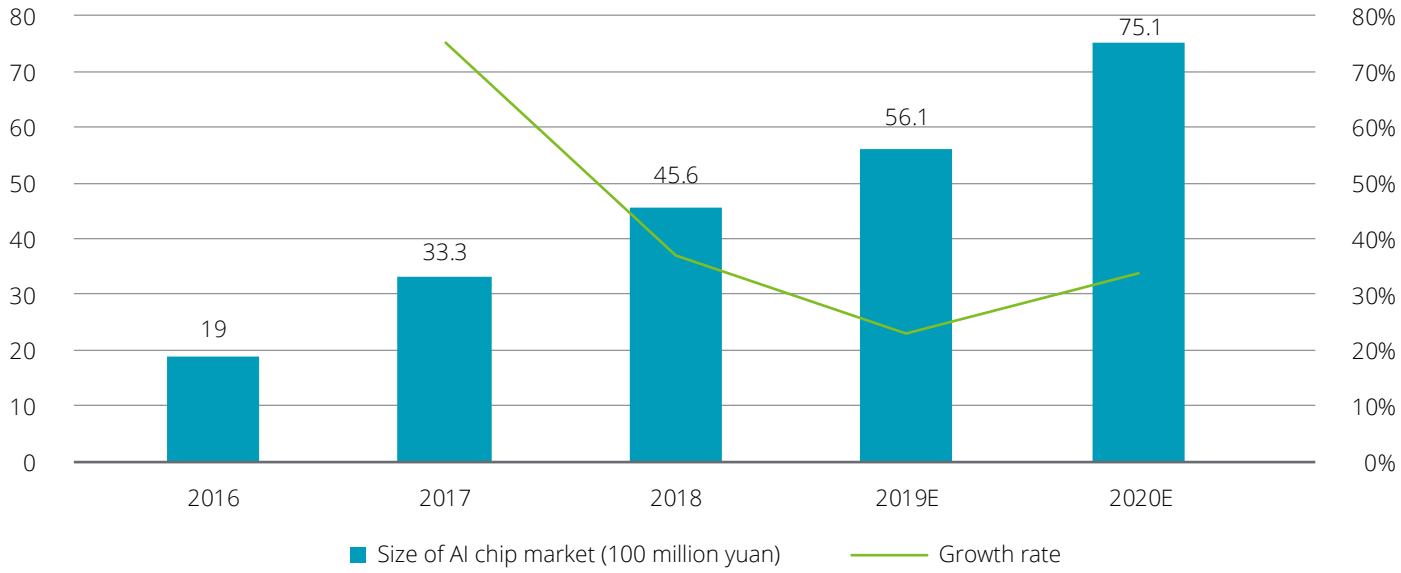
### 1.5 AI supporting technologies are advancing

The troika that driving the advance of AI technologies, algorithm, data and computing power, have been constantly innovated in the past 5 to 10 years. In terms of algorithm, human beings have made breakthroughs in machine learning algorithm, especially the achievement in vision and voice technologies. As for data, the coming of mobile internet era enables explosive growth of data volume.

After long-term development, AI-based algorithm models have been applied in several sub-sectors. Taking machine learning as an example, its core algorithms include: least square method, k nearest neighbor algorithm, k-means algorithm, PCA analysis; core models include: linear regression, logic regression, decision tree, clustering, support vector machine etc. Mainstream algorithm model base enables highly efficient realization of frequent algorithm models: Tensor Flow framework, Caffe framework, CNTK framework collect and integrate data for different algorithm models, they are very practical for algorithm development and application. With constant advance in big data technology, the cost to gain flag data that AI requires for learning was reduced and the speed to process data significantly improves. The efficiency of broadband also improves. Constant iteration of IoT and telecommunication technologies provides infrastructure for the development of AI technologies. By 2020, devices connected with IoT will increase to 50 billion units. As a milestone in the development of telecommunication technologies, 5G will be able to provide up to 1Gbps transmission speed.

Thanks to improvement in the processing capability of chips and the decline of hardware prices, computing power has been greatly improved. So far, most AI computing are executed on GPU chips. However, with technology iteration, cell categories including ASIC and FPGA will become underlying technologies to support the development of AI technologies.

**Figure 1-14: Forecast on the size and growth of China's AI chip market (2016-2020)**




Source: Qianzhan Industry Research Institute, Deloitte Research

**Figure 1-15: Classification of AI chips**

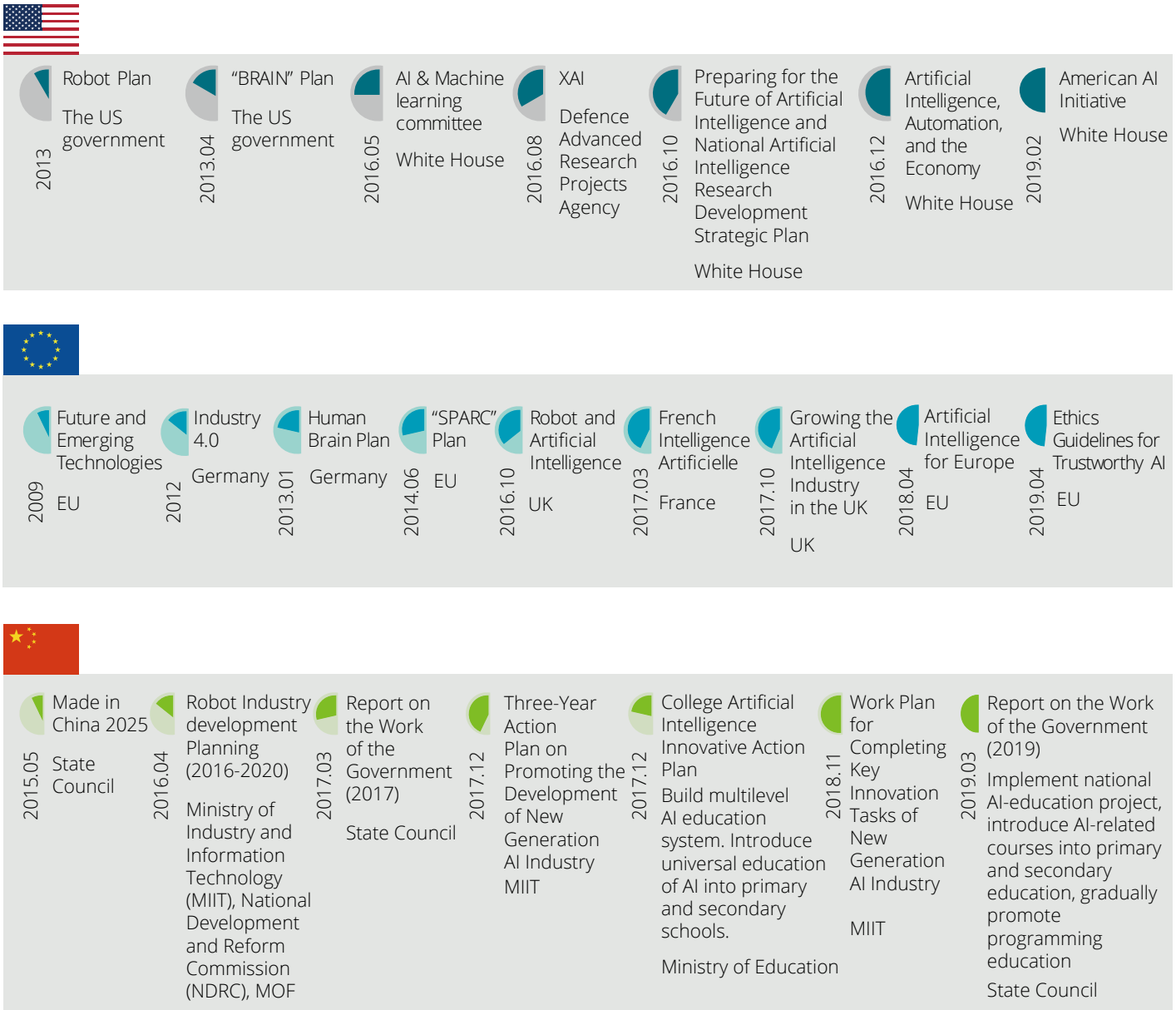
| | Advantages | Disadvantages |
|---|---|---|
| **GPU** | Only a small amount of hardware resources can be applied in control points and most hardware resources can be used as Arithmetic Logic Unit (ALU), which creates conditions for large-scale data processing | Unable to process massive data;<br>Should be based on instruction system;<br>High power consumption; decoding is needed |
| **ASIC** | Don't need instruction and decoding;<br>Focus on data processing or transmission | Customization is needed;<br>Limited functions |
| **FPGA** | Speed and power consumption are superior than general CPUs;<br>Programmable and iterateable (through fast trail-and-error) | Require function DIY;<br>Programming languages are inconsistent |

Source: public information, Deloitte Research

## 1.6 Growing support from top-level policies

Considering the growing impact of AI on social and economic development, many governments have released favorable policies to include AI into national strategies. So far, state-level AI policies have been issued in many countries and regions including the US, China and the European Union.

**Figure 1-16: AI policies released by different countries**




Source: Annual Government Work Report, Public information, Deloitte Research

In 2019, the Chinese government still provide support for the development of AI via some national departments, including MOST, NDRC, National Internet information office, MIIT and Chinese Academy of Engineering. Since 2015, China has published a series of favorable policies, providing great financial, talent and innovation support for AI industry. These policies are also positive signals for the capital market as well as industry interest stakeholders.

To promote the application of AI technologies, the Chinese government have applied homemade AI-based products into several smart city and smart government programs.

**Figure 1-17: China's national AI development policies**

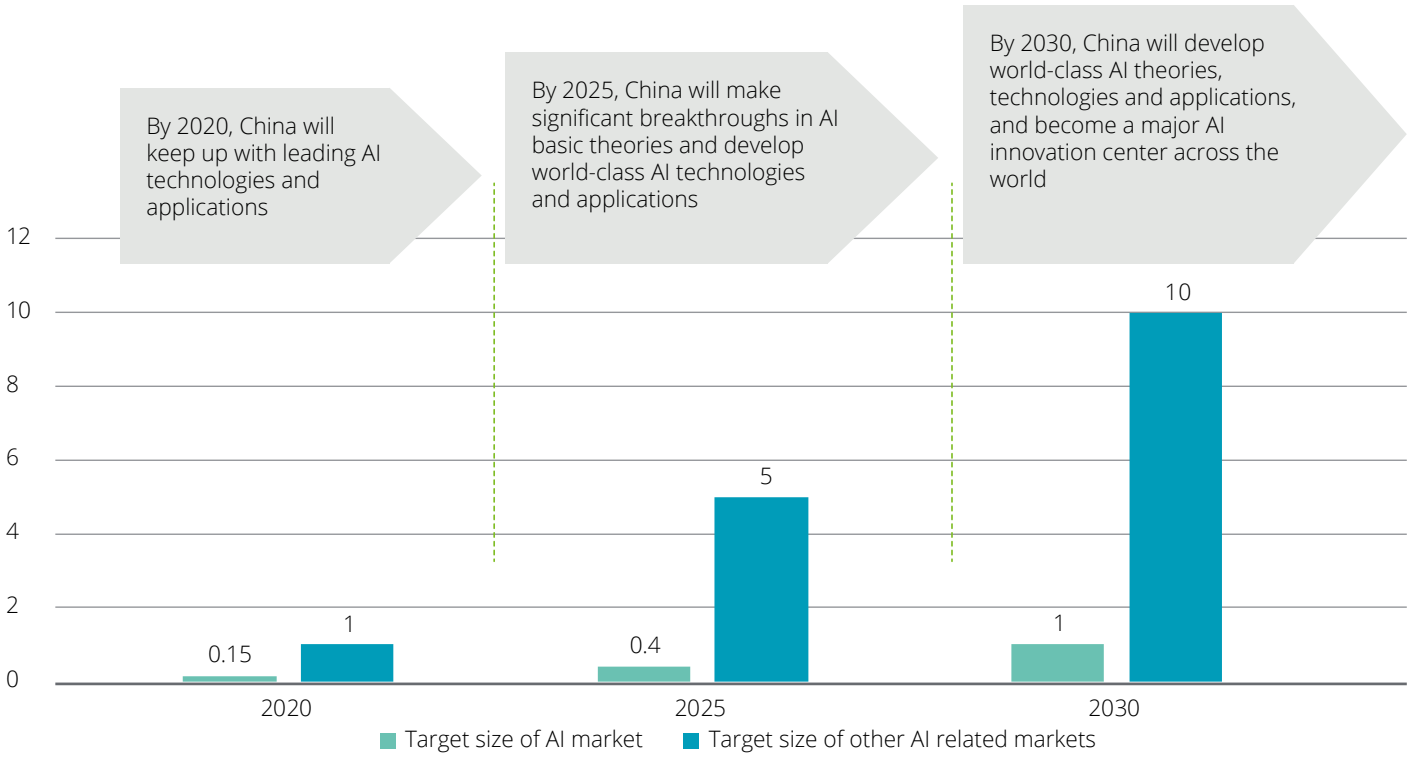
| | | |
|---|---|---|
| **Made in China 2025** | **2015.5** | Develop intelligent equipment, intelligent products and intelligent production |
| **13th Five-Year Plan for Economic and Social Development of the People's Republic of China** | **2016.3** | Include AI development into the 13th Five-Year 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. |

Source: public information, Deloitte Research

From the perspective of strategy, *New Generation of Artificial Intelligence Development Plan* is the first document on systemic deployment of AI technologies in China. It specifies the general idea, strategic goals and tasks and safeguard measures for China's AI development till 2030. The plan clarifies the requirements on underlying technologies, AI technologies as well as AI application, and proposes three development stages (2020, 2025 and 2030) according to the development situation of AI technologies in China.

**Figure 1-18: Three stages of AI development proposed by national strategic planning**




Source: the State Council, Deloitte Research

Regarding local policy, many local governments have made AI development plans based on their actual situations. 19 out 31 provinces/municipalities have issued AI planning, among them, 16 provinces/municipalities have set industry size targets (Shanghai, Beijing, Zhejiang, Guangdong and Sichuan set the top five targets). To greatly promote the implementation and development, cities represented by Beijing, Shanghai, Guangdong and Shenzhen made effective policies, becoming major players and leaders in Chinese AI industry. For example, Beijing has published several measures such as *Several Measures on Promoting Innovative Development of Intelligent Robot Industry in Zhongguancun* and *Guiding Opinions on Accelerating the Development of AI Industry to accelerate the construction of AI industry*. Beijing has set a target higher than other Chinese cities according to national AI strategies.

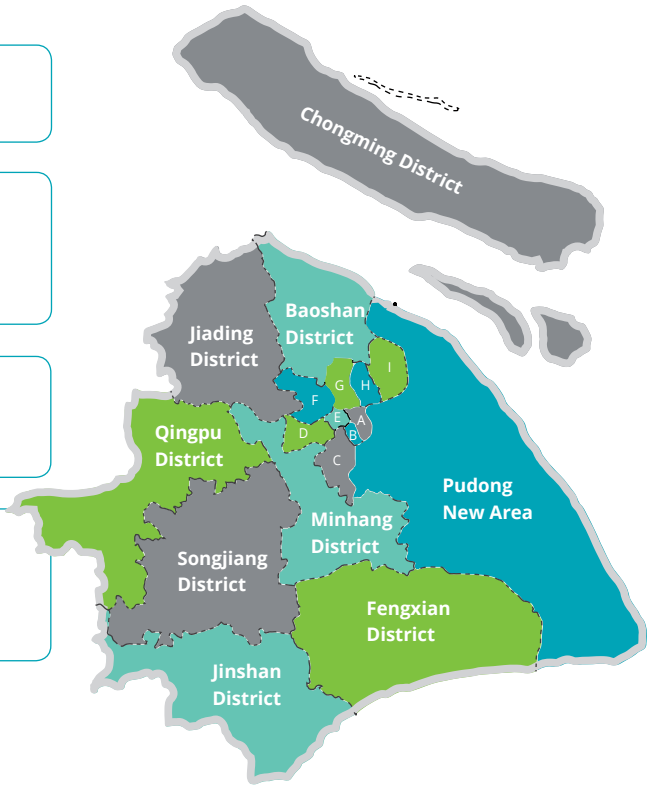
**Figure 1-19: AI development policies issued by local governments**

| Province/ Municipality | Policies |
|---|---|
| **Beijing** | Several Measures of Zhongguancun on Promoting Innovative Development of Intelligent Robot Industry<br>Guiding Opinions of Beijing Municipality on Accelerating Scientific and Innovative Development of AI Industry<br>AI Industry Development Action Plan of Zhongguancun National Independent Innovation Demonstration Zone |
| **Shanghai** | Implementation Measures on Accelerating High-Quality AI Development<br>Implementation Opinions of Shanghai Municipality on Promoting the Development of New Generation AI Industry<br>Outline of the Plan of Shanghai Municipality on Integrating AI into Urban Appearance Improvement Campaign<br>Implementation Details of Shanghai Municipality on Providing Special Support for AI Innovation and Development |
| **Guangdong** | New Generation AI Industry Development Plan of Guangdong Province Action Plan of Guangdong Province on Advancing big data development (2016-2020) |
| **Zhejiang** | New Generation AI Industry Development Plan of Zhejiang Province |
| **Anhui** | New Generation AI Industry Development Plan of Anhui Province<br>Development Plan of China (Hefei) Intelligent Speech and AI Industry Base (China Speech Valley) (2018-2025) |
| **Guangxi** | Implementation Opinions on Implementing the Development Plan of Promoting New Generation AI Industry |
| **Heilongjiang** | AI Development Plan of Heilongjiang Province<br>New Generation AI Industry Development Plan of Shenyang Municipality |
| **Sichuan** | Notice on the New Generation AI Industry Implementation Plan of Sichuan Province |
| **Tianjin** | Three-Year Action Plan of Tianjin Municipality on the Development of New Generation AI Industry<br>Overall Action Plan of Tianjin Municipality on Advancing the Development of AI Technologies<br>Action Plan of Tianjin Municipality on Promoting Precise AI Innovation in 7 Major Industrial Chains |
| **Henan** | Three-Year Action Plan of Henan Province on the Development of Intelligent Manufacturing and Industrial Internet |
| **Hebei** | Three-Year Action Plan of Hebei Province on the Development of Emerging Industries of Strategic Importance |
| **Guizhou** | Smart Guizhou Development Plan (2017-2020) |
| **Hunan** | Several Measures of Changsha Municipality on Accelerating the Development of New Generation AI Industry and Promoting the Construction of National Intelligent Manufacturing Center |
| **Hubei** | 13th Five-Year Plan of Hubei Province on Scientific and Technological Innovation |
| **Fujian** | Implementation Opinions on Accelerating the Development of New Generation AI Industry |
| **Jiangsu** | Smart Jiangsu Construction Action Plan (2018-2020) |
| **Jiangxi** | Several Measures on Accelerating the Development of AI and Intelligent Manufacturing |

Source: public information, Deloitte Research

For instance, Shanghai is improving and refining AI development strategies and policies in order to build a national AI development highland. Following *the Implementation Opinions on Advancing the Development of New Generation AI*, Shanghai published the *Implementation Measures of Shanghai Municipality on Accelerating High-quality AI Development* in September 2018. The measures include 22 detailed rules, covering AI talent cultivation, data and resource sharing and application, industry layout and cluster, government capital attraction and support. These new rules can be combined with existing AI policies to effectively use various capital, projects and service resources and create broad development space for Shanghai's AI industry.

**Figure 1-20: Development plan of AI applications in Shanghai**




**Baoshan District**
Intelligent hardware

**Xuhui District**
Intelligent healthcare
Intelligent chip design
Intelligent security

**Minhang District**
Intelligent recognition
Intelligent healthcare

**Songjiang District**
Intelligent healthcare
Intelligent chip design
Intelligent security

**Yangpu District**
Intelligent education
Intelligent recognition

**Putuo District**
Intelligent security
Intelligent hardware

**Changning District**
Intelligent recognition
Intelligent retail

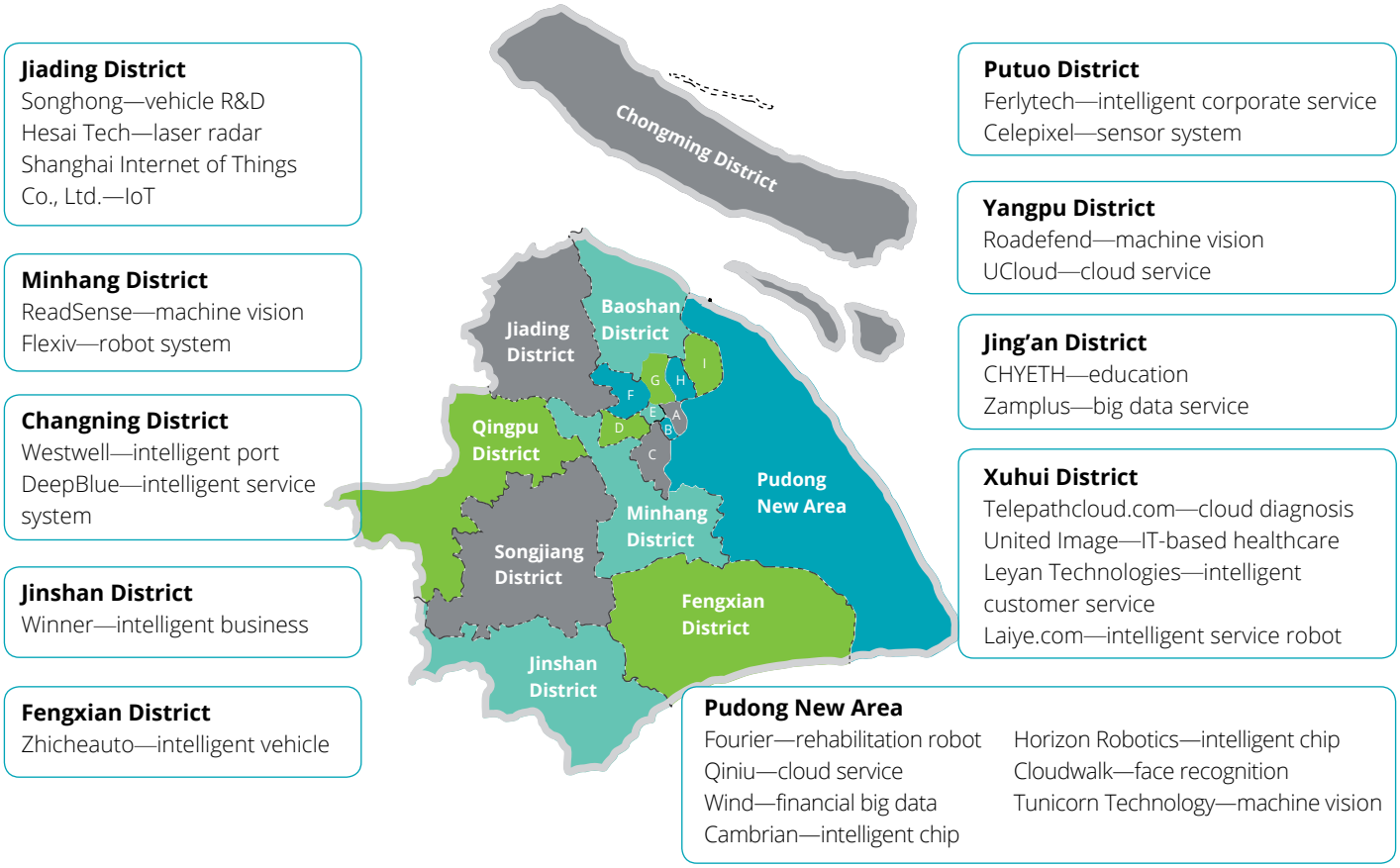
**Pudong New Area**
Intelligent chip design
Intelligent speech recognition
Intelligent manufacturing

A Huangpu District B Luwan District C Xuhui District D Changning District E Jing'an District F Putuo District G Zhabei District H Hongkou District I Yangpu District

Source: Shanghai Municipal Economy and Information Technology Commission, Deloitte Research

After the launching of the science and technology innovation board in Shanghai on 13 June 2019, the integration of investment and industries will be further enhanced, providing financial support for AI innovation. As of 5 July, 25 companies have successfully registered for the sci-tech board, five of them are Shanghai-based enterprises such as Montage Technology, a star AI company in chip service sector. In terms of investing institution, Shanghai has many well-capitalized and influential financial companies. In terms of investment project, Shanghai has established incubation parks for AI innovation star-ups engaged in hot areas such as healthcare, education and big data. Moreover, Shanghai municipal government also provide support for a series of companies specialized in AI innovation. Most of these startups successfully expand and even gain tens of millions of financing for advanced technologies and high business value, which are be very likely to apply for listing on the sci-tech board.

**Figure 1-21: Distribution of Shanghai-based AI innovation companies**




A Huangpu District B Luwan District C Xuhui District D Changning District E Jing'an District F Putuo District G Zhabei District H Hongkou District I Yangpu District

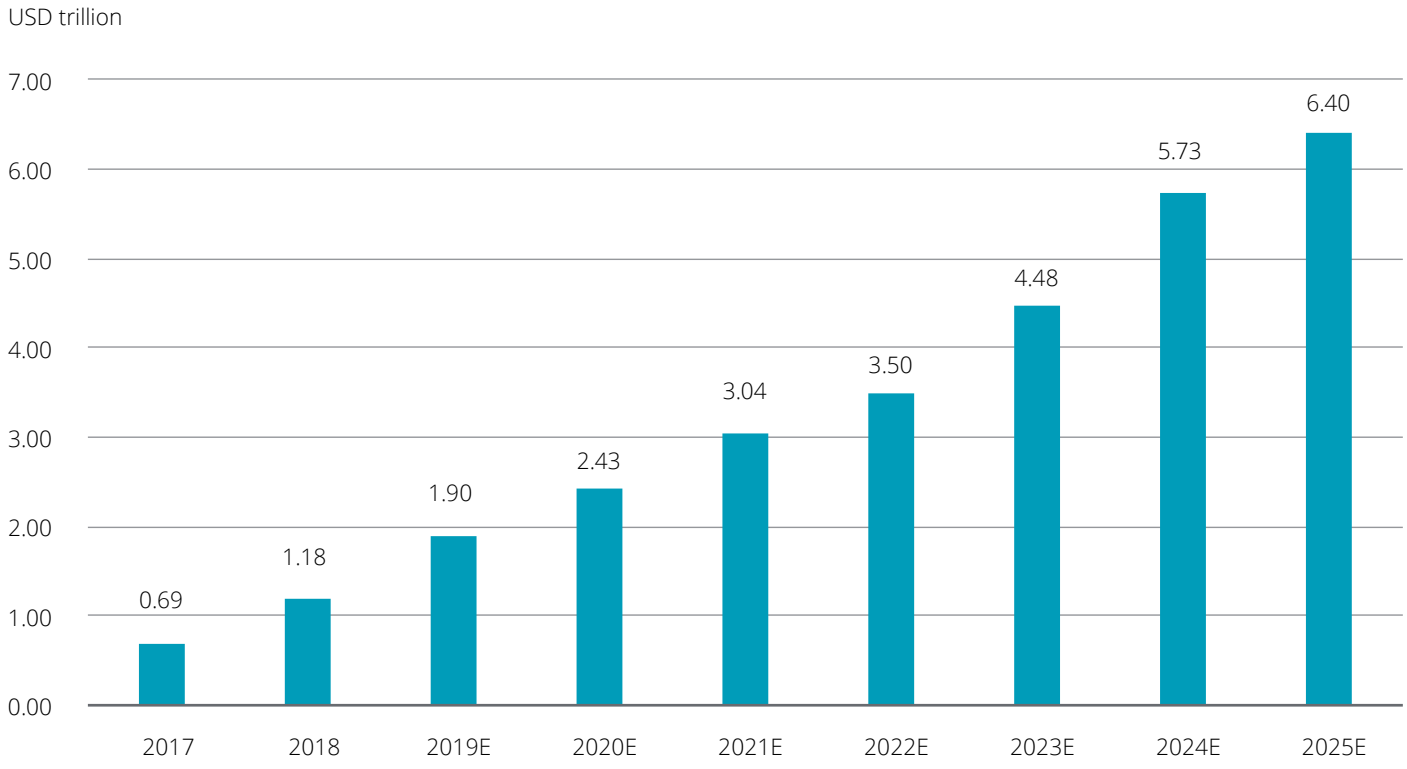
Source: Shanghai Municipal Economy and Information Technology Commission, Deloitte Research

In summary, AI industry is flourishing in many places of China. Provinces and municipalities respond actively after the release of national AI development plan. Due to technology, talent and industry advantages, first-tier cities have become hot areas of AI industry development in China and will promote the development of AI industry in surrounding areas.

### 1.7 Over USD 6 trillion global AI market

AI will improve social productivity and bring disruptive changes to people's production and life including lower labor cost, better products and services, new markets and more employment opportunities. Increasingly aware of the importance of AI at the economic and strategic levels, governments and businesses across the world are investing in AI application concerning national strategic practices and business activities. The global AI market is likely to see phenomenal growth and achieve a market value of over USD6 trillion by 2025 and a CAGR of 30% from 2017 to 2025.

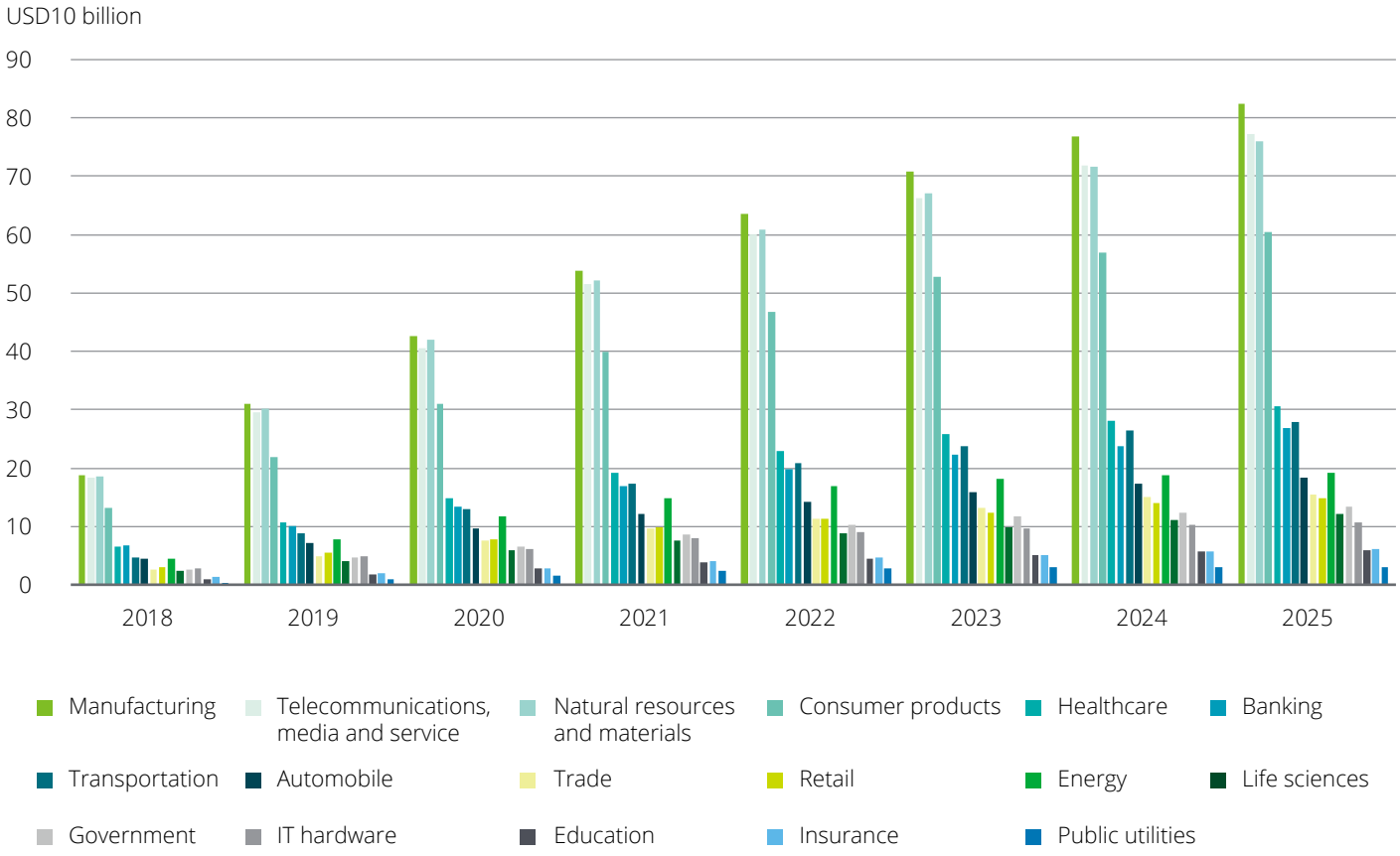
**Figure 1-22: Global AI market size**




Source: Deloitte Research

Traditional industries with large market size will maintain their leadership. Manufacturing, telecommunications, media and service, and natural resources and materials are expected to be ranked among the top three in 2030, respectively accounting for 16%, 16% and 14% of the market share. Manufacturing is the fastest-growing industry, with large manufacturers accelerating their digital transformation to realize smart management, smart factories and smart logistics. As AI application in education is expanding across the whole learning process, growth in this sector should not be underestimated.

**Figure 1-23: AI market size (by industry)**




Source: Gartner

China's AI industry has reached a market size of over RMB100 billion. This figure is expected to rise to RMB160 billion by 2020, and is likely to stimulate more than RMB1 trillion value in other AI-related industries.[19] The scale of artificial intelligence related industries in Beijing, Shanghai, Zhejiang, Jiangsu and Guangdong is in the forefront of all provinces and municipalities, and is expected to reach 140 billion, 130 billion, 270 billion, 100 billion and 280 billion respectively in 2020.

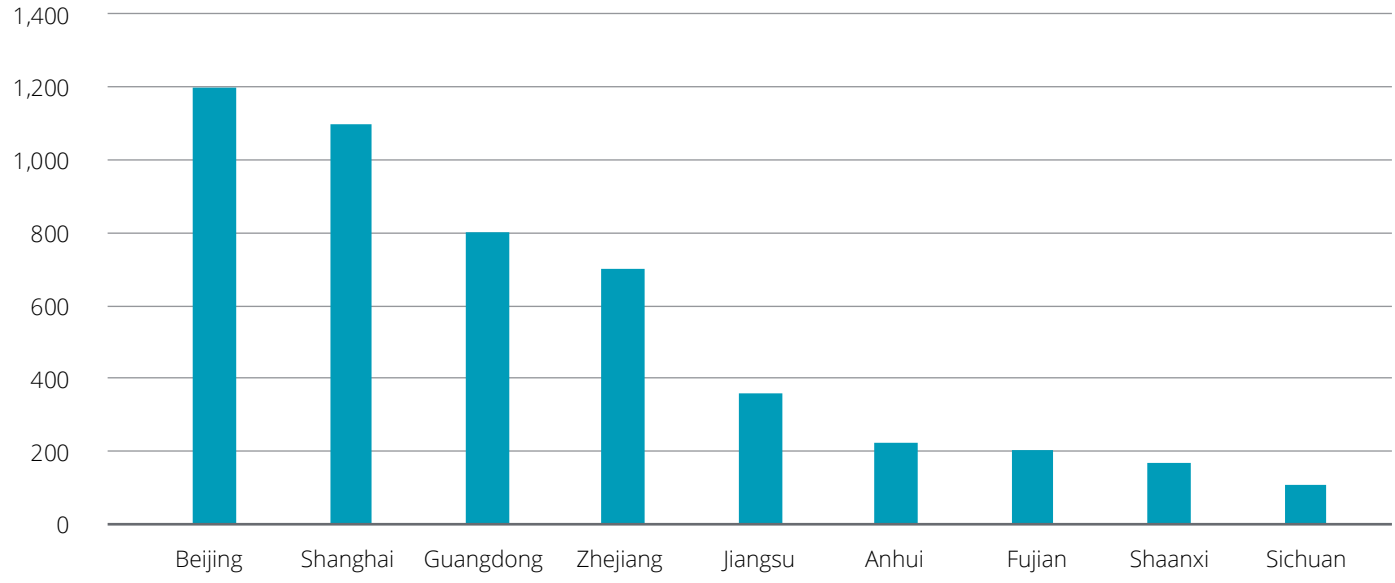
Since the issuance of *the Implementation Opinions on Promoting the Development of a New Generation of Artificial Intelligence in Shanghai*, Shanghai has embraced rapid development of AI industry, which is likely to achieve a market size of RMB120 billion in 2019. Based on geographical advantages of Yangtze River Delta, Shanghai's AI companies have access to sufficient quality talent and capital resources. Significant enterprise cluster effect will drive the increase of company and industrial size.

### 1.8 Large number of AI companies located in the Beijing-Tianjin-Hebei Region, Yangtze River Delta and Pearl River Delta

AI technology has extended across various industries for business application. With general confidence of all parties including governments and companies about the future of the technology, AI will undoubtedly become an important driver for economic development.

Local governments are publishing guidance on AI-related industry planning, aiming to promote industrial upgrading and change of economic growth drivers. They take active measures to create a desirable business environment by providing preferential tax policies and subsidies, brain gain and optimizing government affairs system, with the purpose to attract well-positioned enterprises and develop local AI companies.

**Figure 1-24: Distribution of AI companies in China**



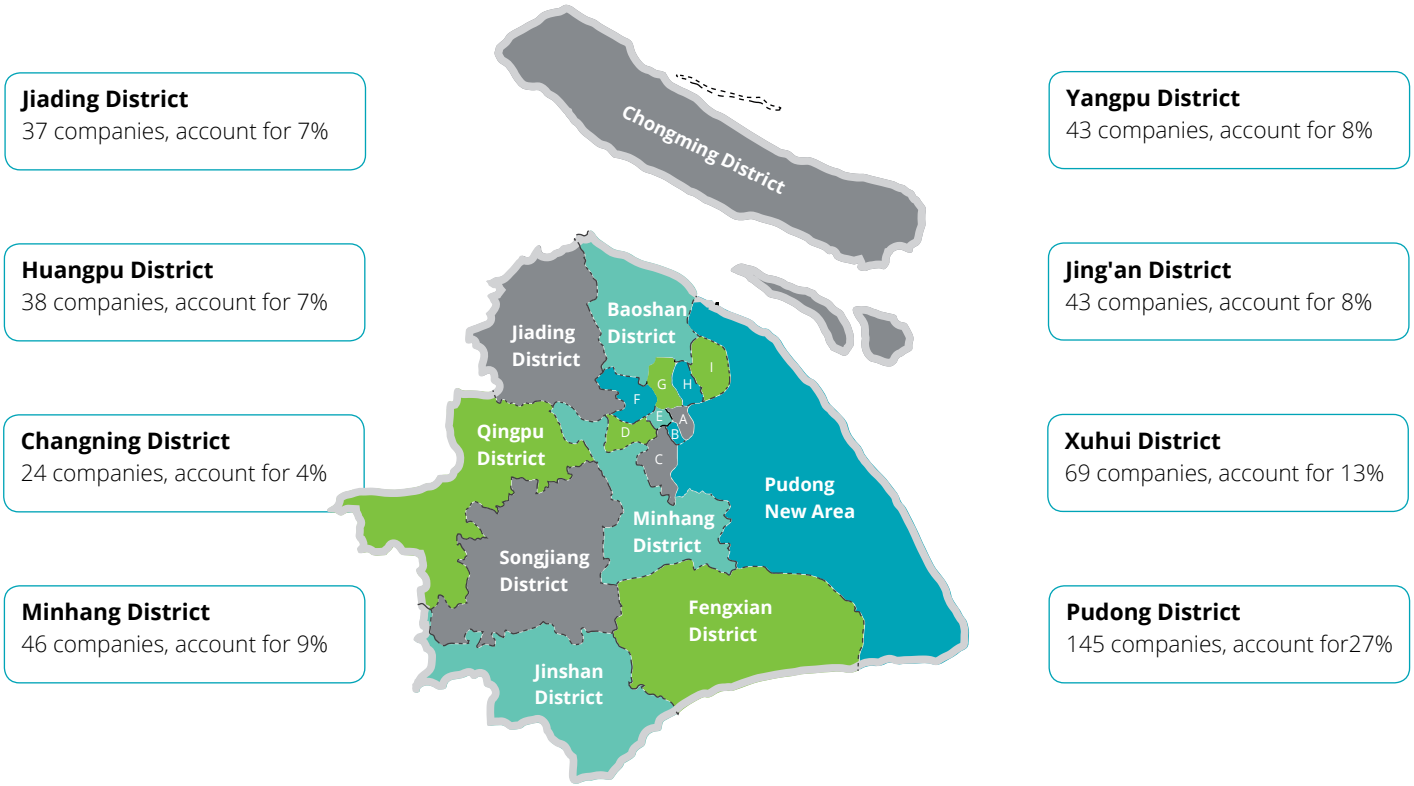

Source: Publically available information, Deloitte Research

19. Speech of the Ministry of Industry and Information Technology of PRC on "World Telecommunication and Information Society" Day in 2018

Driven by policies and capital, AI companies see a rapid growth in number. According to incomplete statistics, there are over 4,000[20] AI companies across China, mostly located in the Beijing-Tianjin-Hebei Region, Yangtze River Delta and Pearl River Delta. Sichuan and Chongqing in western China are also the hubs for AI companies, as many traditional manufacturers in the region need to leverage AI technology for intelligent transformation. Government's incentive policies are also attracting AI companies to the region.

Beijing, Shanghai, Shenzhen and Hangzhou are tier-one cities attracting the most AI companies, with more than 600 in each of them.

**Figure 1-25: Distribution of key AI companies in Shanghai**




A Huangpu District B Luwan District C Xuhui District D Changning District E Jing'an District F Putuo District G Zhabei District H Hongkou District I Yangpu District

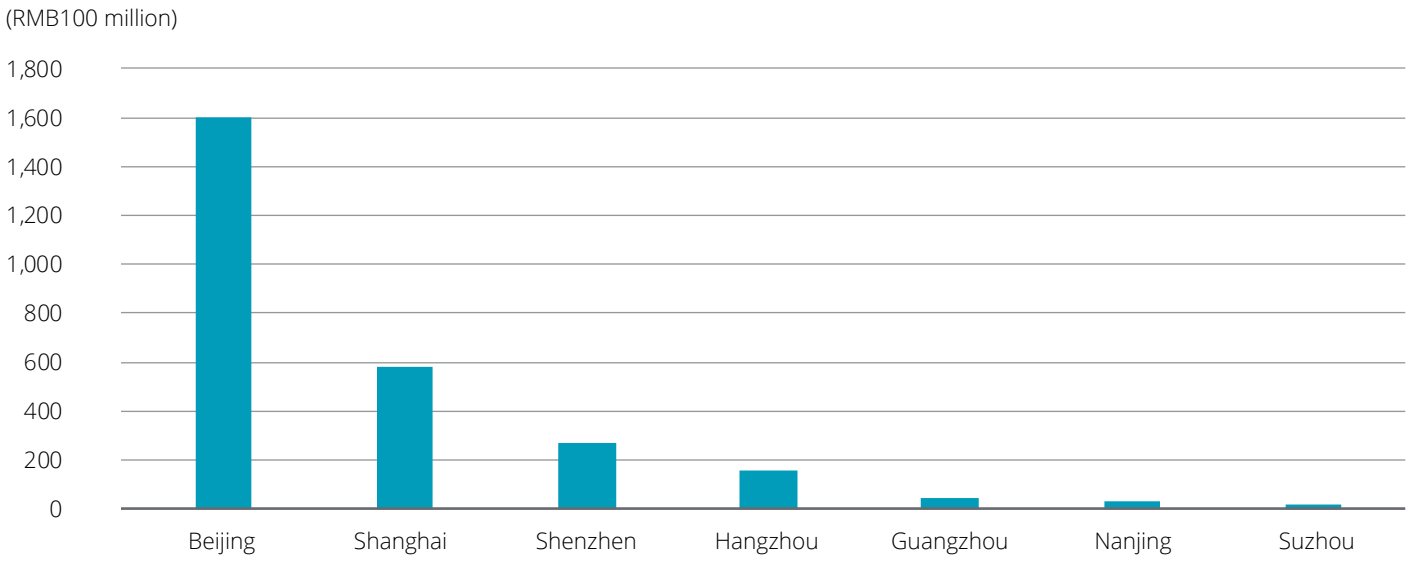
Source: ASKCI Consulting, Deloitte Research

20. China AI Development Report2018, Tsinghua University

**Investment and funds raised: AI startups in Beijing and Shanghai rank the top in investment and funds raised**

An active capital environment can improve a city's competitiveness in AI industry, as it is favorable for AI startups to improve technologies, attract users and develop markets, and may facilitate connection between up-stream and down-stream players across the AI industrial chain to trigger scale effect.

**Figure 1-26: Funds raised by AI startups in different cities (2015-1H 2019)**




Source: ITJUZI.COM, Deloitte Research

As startups are pioneers in the research and development as well as business application of new technologies, the amount of capital raised by this group indicates the prospect of new technologies in the region. AI technology has been applied in a wide range of sectors including finance, transportation, healthcare and manufacturing for business purpose. Funds raised by startups will provide financial support for the application of AI in more industries.

Since 2015, AI startups in Beijing and Shanghai have respectively raised more than RMB50 billion, with a record of RMB159.9 billion and RMB58.2 billion. Most AI startups with strong technical capabilities in China are located in Beijing and Shanghai, where customers are more willing to use new technologies. Therefore, there are more opportunities for AI application in the two cities.

**Variance in the number of universities, colleges and other research organizations: Beijing is strongly competitive, while Shanghai mainly relies on universities and colleges, Shenzhen on companies and Hangzhou on limited platforms**

Universities, colleges and other research organizations are important platforms for the research and development of AI technology. China has surpassed the US in the number of AI research papers since 2014, leading far ahead of other countries. It is closely related to the fast development of universities, colleges and other organizations engaged in AI research, which are also major applicants for AI patents. Thus, analysis of these organizations will provide insights into the technological competitiveness of related cities.

**Figure 1-27: Characteristics of different cities by universities, colleges and other organizations engaged in AI research**

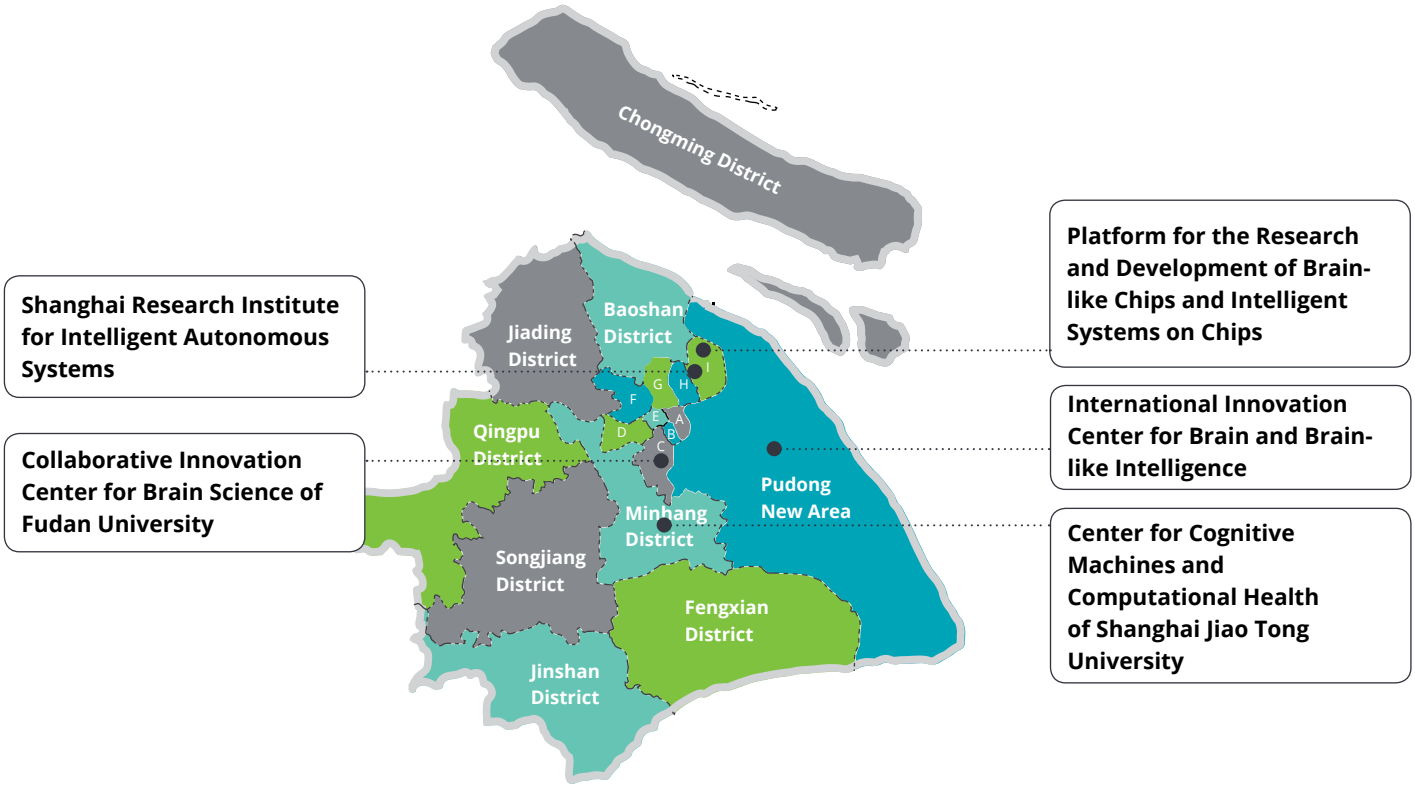
| | Characteristics | Universities and colleges | Governmental or research institutes and labs of universities and colleges | Corporate labs |
|---|---|---|---|---|
| **Beijing** | • Most competitive in AI research | More than 50%:<br>• Tsinghua University<br>• Peking University<br>• Beihang University<br>• Institute of Automation, Chinese Academy of Sciences | More than 10:<br>• National Laboratory of Pattern Recognition<br>• CSAI<br>• National Engineering Laboratory for Deep Learning Technology and Applications<br>• Institute for Artificial Intelligence, Tsinghua University<br>• Peking University Law Artificial Intelligence Laboratory | • 360<br>• Baidu<br>• Xiaomi<br>• Meituan<br>• JD.com<br>• Sinovation Ventures<br>• Toutiao<br>• Lenovo<br>• UBTECH |
| **Shanghai** | • Mainly relying on universities, and colleges, with corporate research institutes/ labs (although less than Beijing) laying academic foundation | Many universities and colleges:<br>• Shanghai Jiao Tong University<br>• Fudan University<br>• Tongji University | • SJTU-Versa Computer Science and AI Joint Lab<br>• AI adaptive education lab jointly established by Chinese Academy of Sciences and Squirrel AI | • SAIC Motor<br>• Philips<br>• SenseTime<br>• Tencent<br>• Squirrel AI<br>• Microsoft |
| **henzhen** | • Mainly relying on corporates | • Shenzhen University<br>• Southern University of Science and Technology | Mainly led by the government:<br>• Shenzhen Academy of Robotics<br>• Shenzhen Institute of Artificial Intelligence and Big Data | • Tencent<br>• Huawei<br>• ZTE |
| **Hangzhou** | • With gap from Beijing, Shanghai and Shenzhen | • Zhejiang University | | • Alibaba<br>• NetEase<br>• Geely Auto |

Source: Publically available information, Deloitte Research

These four cities have different characteristics in universities and colleges and other institutes engaged in AI research. Beijing is the most completive in AI research, with over 50% of China's research universities and colleges and more than 10 national labs. Internet giants located in Beijing such as Baidu, JD.com and Meituan are establishing corporate labs, investing large amount of capital in AI research and development. Shanghai is ranked among the top nationwide in AI development, based on leading universities including Fudan University, Tongji University and Shanghai Jiao Tong University. As a hub of many tech enterprises such as Tencent, Huawei and ZTE, Shenzhen is a key player in AI research and development. Meanwhile, the local government is also making efforts to improve the city's technological competitiveness, as evidenced by the establishment of Shenzhen Academy of Robotics and Shenzhen Institute of Artificial Intelligence and Big Data. Hangzhou lags behind Beijing, Shanghai and Shenzhen in the number of universities and colleges, university and college labs and corporate labs, mainly relying on giant Alibaba in AI research.

Shanghai has obtained a leading position nationwide in the establishment of research and technical platforms. Many AI function platforms have been established in Shanghai, including Shanghai Research Institute for Intelligent Autonomous Systems, Collaborative Innovation Center for Brain Science of Fudan University, Platform for the Research and Development of Brain-like Chips and Intelligent Systems on Chips, International Innovation Center for Brain and Brain-like Intelligence and Center for Cognitive Machines and Computational Health of Shanghai Jiao Tong University. Shanghai is also considered as a hub of AI-related research, education and production, attracting tech giants such as Alibaba, Tencent, SenseTime, MEGVII, Microsoft and Amazon to locate their AI R&D bases in the city and establish joint labs with local universities and colleges. These joint labs will enhance the cooperation between businesses and academic community in AI research, providing strong intelligent support for the development of Shanghai's AI industry.

**Figure 1-28: Distribution of AI research centers in Shanghai**




A Huangpu District B Luwan District C Xuhui District D Changning District E Jing'an District F Putuo District G Zhabei District H Hongkou District I Yangpu District

Source: Publically available information, Deloitte Research

**Figure 1-29: AI giants' research centers in Shanghai**

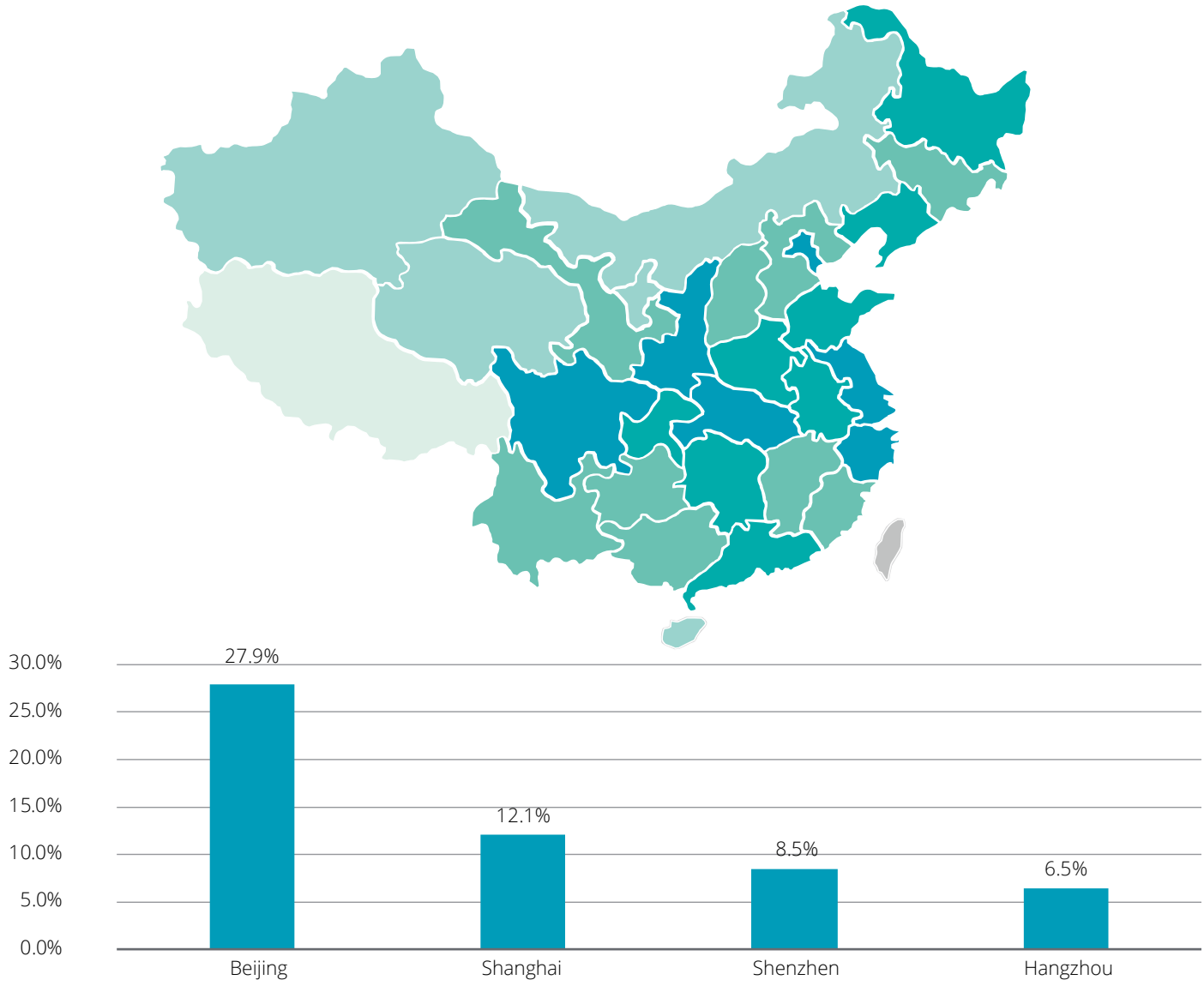
| Company name | Cooperation |
|---|---|
| Alibaba | AI Innovation Center |
| Tencent | Tencent Computer Vision Research Center and head office of Eastern China |
| Amazon | AWS AI Research Institute (Shanghai) |
| Microsoft | Microsoft Research Asia (Shanghai) |
| iFLYTEK | iFLYTEK Shanghai Institute of Artificial Intelligence and Brain Science |
| SenseTime | Global R&D Headquarters with an investment of RMB6 billion |
| MEGVII | Joint lab with ShanghaiTech University |
| Yixue Education—Squirrel AI | Artificial intelligence self-adaptive learning Institution |

Source: Deloitte Research

**AI talent resources: concentrated in economically developed regions**

AI competition comes down to talent competition. AI talent resources are unevenly distributed in China, mainly concentrated in the Beijing-Tianjin-Hebei Region, Yangtze River Delta and Pearl River Delta. Central and western regions of China, in particular the area along Yangtze River, have also attracted many AI talents. Beijing takes the first place among all Chinese cities in the percentage of AI talents, with a prominent figure of nearly 28%, which is about twice as much as that of the second-place city Shanghai (12.1%). Shenzhen and Hangzhou are ranked among the tier-two with a percentage of less than 10%.

**Figure 1-30: AI talent percentage of different cities**

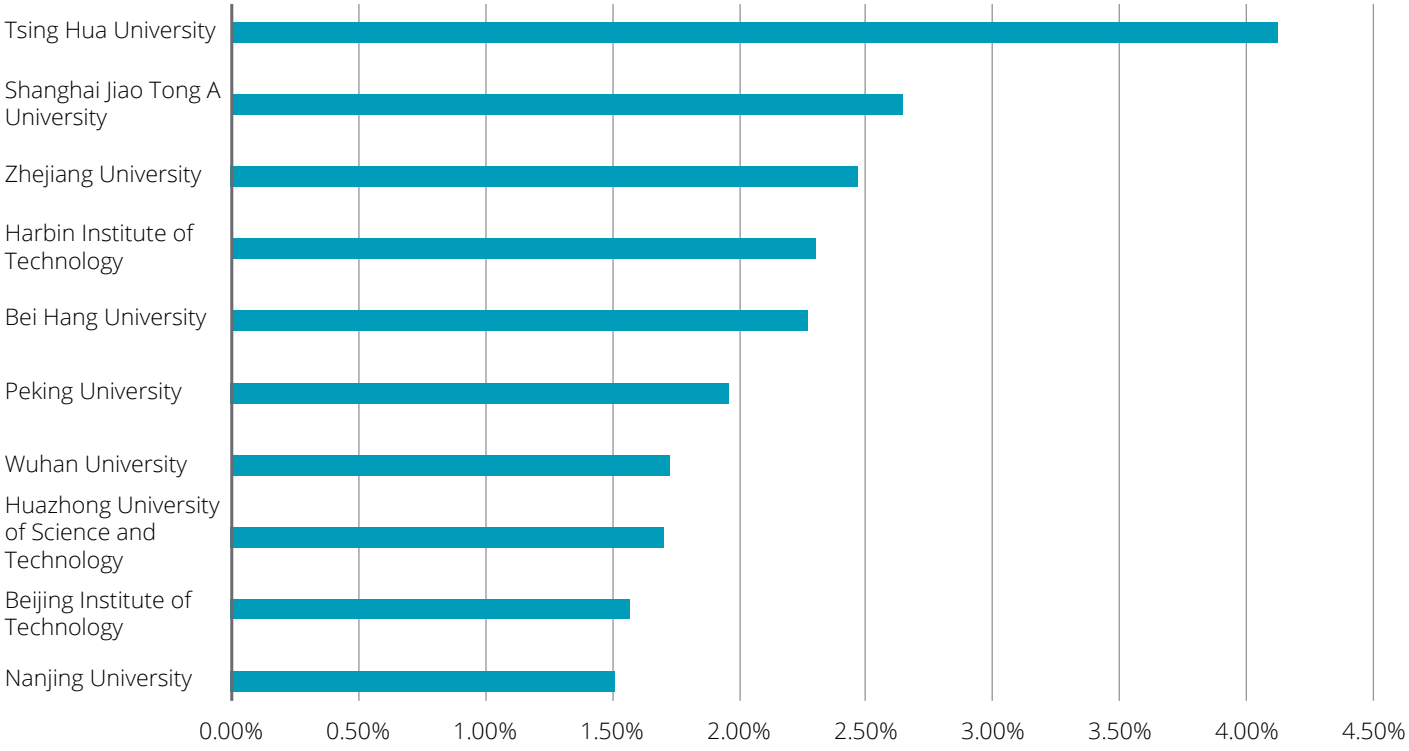



Source: Global AI Talent White Paper, Report on China's AI Development 2018, Tencent, Deloitte Research

Note: The color indicates the number of AI talents in each province or city; the darker the color, the more AI talents there are. The bar chart illustrates AI talent percentage=number of AI talents in each city/total number of AI talents in China.

Domestic universities and colleges as well as research institutes are the major incubators of AI talents. First-tier cities such as Shanghai have significant advantages in developing AI industry, with a large number of high-quality research and educational platforms. Over 75% of AI talents in China are from local universities and colleges. With strong research capabilities, Tsinghua University, Shanghai Jiao Tong University and Zhejiang University are the major sources of AI talents.

**Figure 1-31: Percentage of AI papers published in international journals across different universities**

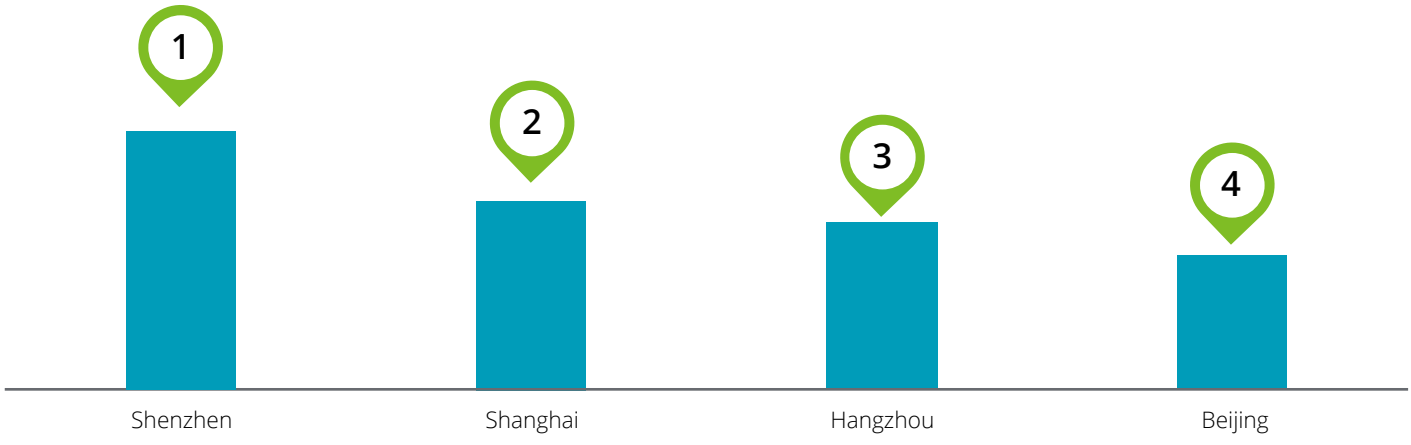



Source: Report on the Development of Next-generation Artificial Intelligence Industry in China 2019, Deloitte Research

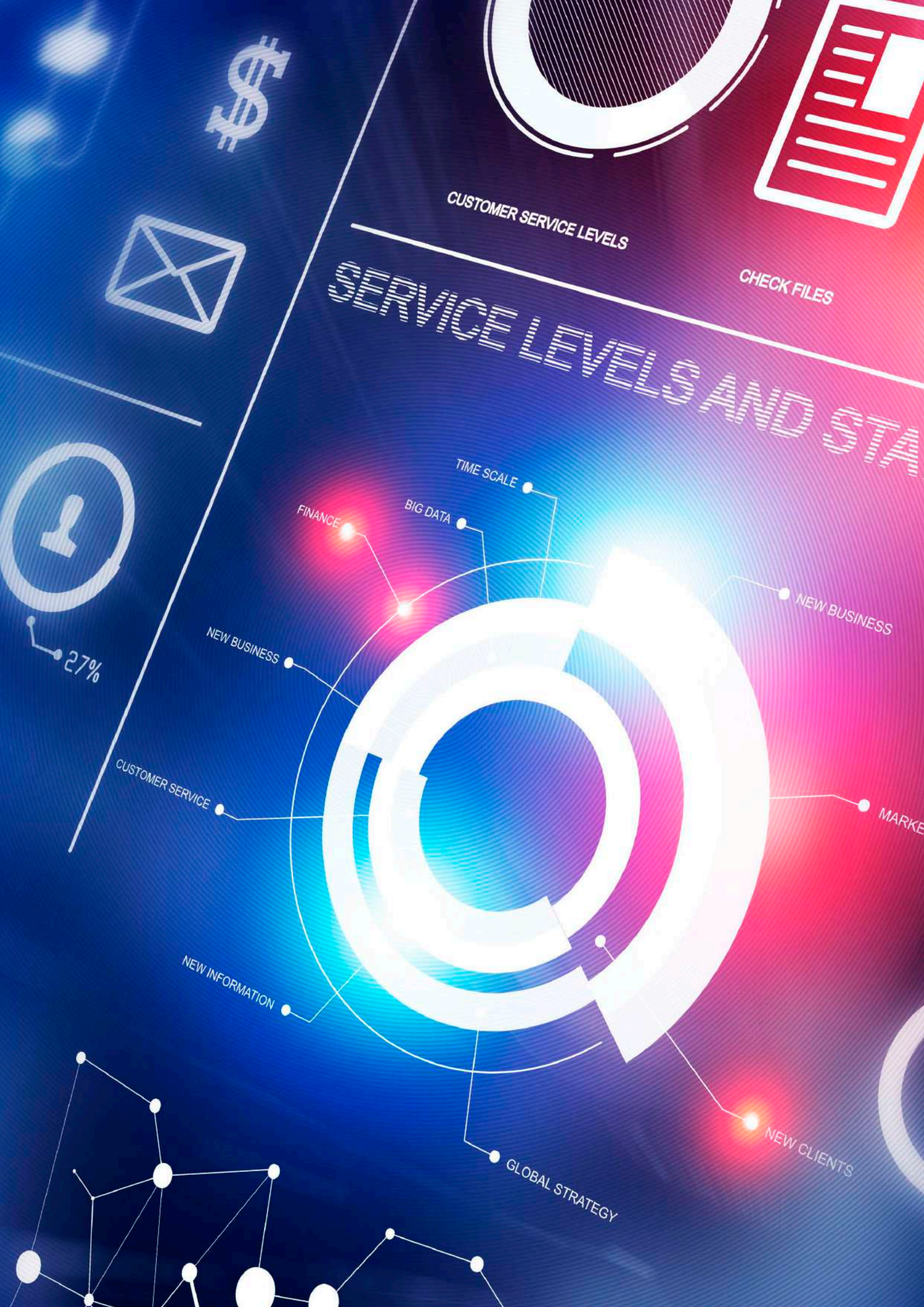

**Intelligent city management: significantly influenced by policies with Shenzhen, Shanghai and Hangzhou taking the lead**

Integration of information technology into government affairs system is widely applied to improve city management efficiency under a smart city framework. This approach will drive data integration among different sectors to provide data support for intelligent city management. Shenzhen, Shanghai and Hangzhou stand out in intelligent city management, as governments of these cities are early information technology adopters that have generally realized resources sharing and collaboration among departments and have established online-approving systems. Beijing's low ranking is attributed to more considerations of the government in intelligent city management.

**Figure 1-32: Rankings of cities by intelligent city management**




Source: Super Smart City, Deloitte Research

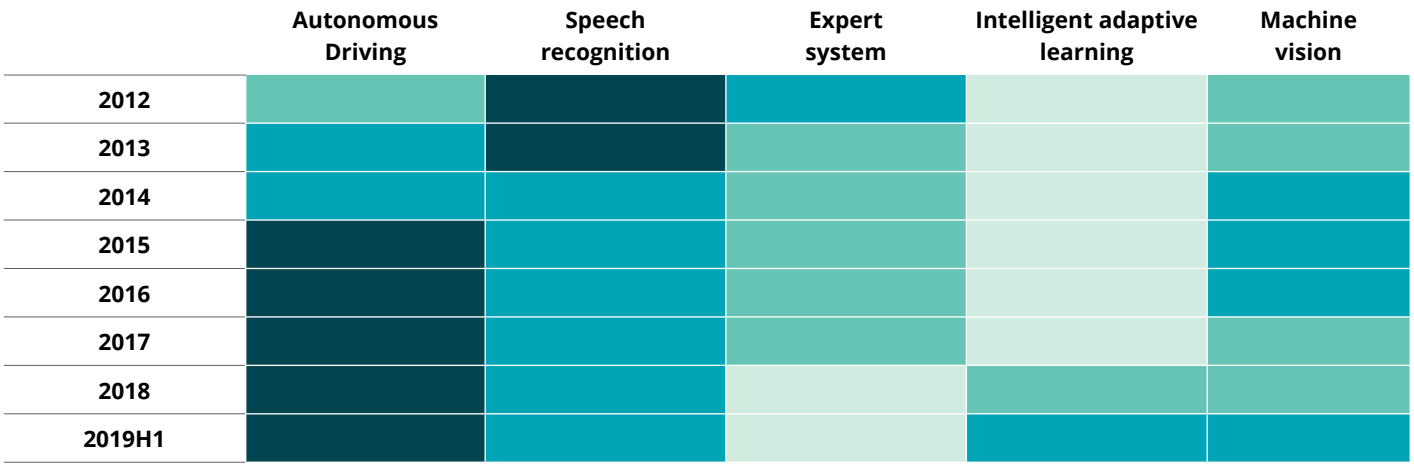

CUSTOMER SERVICE LEVELS
CHECK FILES
SERVICE LEVELS AND STA
27%
TIME SCALE
FINANCE
BIG DATA
NEW BUSINESS
NEW BUSINESS
CUSTOMER SERVICE
NEW INFORMATION
GLOBAL STRATEGY
NEW CLIENTS

# 2. Development of AI technologies

## 2.1 Increasingly sophisticated AI technologies

AI technologies including machine learning, natural language processing, computer vision and intelligent adaptive technology have made great strides over the last decade. According the data of Tsinghua University, computer vision, speech processing and natural language processing are applied most extensively in China, with each accounting for 34.9%, 24.8% and 21% of AI application in the market.

**Figure 2-1: Ranking of AI technologies by popularity**




Source: Baidu Index, Deloitte Research

**The implementation of autonomous and unmanned systems is around the corner:** With the development of AI and machine learning, self-driving cars, drones and medical robots have achieved significant progress, mainly attributed to autonomous and unmanned system algorithm. Deep learning proves to be able to handle complex tasks. Modern computing equipment such as GPUs and computing frameworks including Caffe, Theano and Tensor Flow can support designers and engineers to establish innovative autonomous and unmanned systems. Intelligent bicycle systems developed by Alibaba AI Labs can provide round-the-clock centimeter-level positioning which applies to all scenarios. Baidu's self-driving technology has five core capabilities including obstacle perception, decision making and planning, cloud simulation, high-precision map service and end-to-end deep learning. Horizon Robotics has launched deep learning processor IPs and platforms for self-driving sector. As for industrial application, Westwell has taken some initiatives in exploring unmanned cargo.

**Speech recognition technology** becomes a "must win" for giants: Speech recognition enables machines to automatically recognize and understand human language and convert to texts and instructions, using signal processing and recognition technologies. Relevant application scenarios include smart TV, intelligent vehicle information systems, call centers, voice assistants, intelligent mobile terminals and smart appliances. Major platforms such as Baidu, iFLYTEK and Sogou have achieved an accuracy of over 97% in speech recognition. Meanwhile, emerging tech companies including Unisound are also playing prominent roles in speech recognition sector. iFLYTEK's deep fully convolutional neural network-based speech recognition framework possesses an accuracy rate of 98% in input recognition. Sogou's speech recognition technology is able to support a highest dictation rate of 400 words per second. Alibaba AI Labs has developed AI-based shopping products with speaker recognition function.

**Intelligent adaptive learning technology is increasingly sophisticated:** As one of the most disruptive technologies in education industry, intelligent adaptive learning enables learning systems to provide personalized education, by simulating one-to-one education scenarios. Compared with the traditional teaching model designed for all students, intelligent adaptive learning system brings personalized learning experience to students, improving their involvement and efficiency in learning. Intelligent adaptive learning technology has been used in the US and Europe for more than ten years, with over 100 million users across different ages. Both product and technology have evolved to an advanced level in these regions. China, however, is still at the initial stage in the application of intelligent adaptive learning technology, lagging behind in data accumulated. Despite of such situation, China is likely to catch up from behind, based on large population and rapid development. Intelligent adaptive learning companies in China represented by Yixue Education—Squirrel AI have been applying a wide range of technologies such as Bayesian network, Deep Neural Network Evolutionary algorithms, Transfer learning, and the other machine learning algorithms.

**Computer vision technology is developing fast:** Computer vision is a machine vision technology to identify, track and measure objects with computers instead of human eyes. It has been applied in a wide range of scenarios including smart home, audio-visual interaction, augmented reality, virtual reality, image search for products on e-commerce platforms, tag search, beauty effects, intelligent security, livestream regulation, video platform marketing and three-dimensional analysis. Significant progress has been achieved in the application of computer vison in these scenarios. This filed has attracted active investment from tech giants and unicorn companies, represented by Baidu, Tencent, Hikvision, Tsinghua University, Chinese Academy of Sciences and other business and research organizations. PyramidBox of Baidu is a deep learning-based face detector; Hikvision proposes to predict human body central axis rather than labelling frame against the dim target problem in pedestrian detection. Tencent Youtu and the Chinese University of Hong Kong jointly launched PANet at CVPR2018, which aggregates low-level and high-level features based on Mask R-CNN and integrates the feature grids obtained from sampling candidate areas on multiple feature levels by ROI Align to support subsequent prediction. Innovative companies such as CloudWalk Technology, DeepBlue Technology and Qiniu are leading in computer vision technology.

## 2.2 Steady progress of open AI platform establishment

A wide range of industries and broad solution market provide significant advantages for China's AI development. In addition to the support from large volumes of search data, considerable product lines and extensive industries, the efforts of overseas and domestic tech giants in promoting open source tech communities have helped startups break technology barriers and apply AI directly in the research and development of end-user products. AI technologies have been used in various vertical sectors including medical care, health, finance, education and security.

As business application of AI technologies is accelerating, tech giants and emerging AI startups have obtained their technology advantages. Technologically leading AI companies are establishing their open AI platforms, aiming to make better use of tech advantages to drive business growth and facilitate the development of AI industry.

AI platforms provide tools for AI application development. These tools enable developers to create business solutions through platforms, combining intelligence, decision-making algorithms and data. Some AI platforms provide solutions to basic application development, based on Platform as a Service (PaaS) function enabled by pre-set algorithms and simple frameworks, while other platforms leave developers to complete application development and programming by themselves. These algorithms can provide functional support for machine learning technologies such as image recognition, natural language processing, speech recognition, system recommendation and predictive analysis.

Open AI platforms intend to support the establishment of an AI industrial chain which expands technology innovation from the source to the whole industry. Open platforms connect two ends of the industrial chain, building a bridge between developers and research institutions and enhancing the connection between downstream companies with other organizations across the industrial chain. For example, an open AI platform mainly designed for image recognition can share related technologies with startups that seek to develop business in this field.

**Figure 2-2: Open technology and application platforms developed by Chinese and foreign companies**

| Related fields of the open platforms | China | Overseas |
|---|---|---|
| **Autonomous driving** | Baidu Autonomous Driving | NVIDIA DRIVE Platform |
| **Smart city** | Alibaba City Brain | IBM Watson, Microsoft Citynex |
| **Intelligent healthcare** | Tencent Medical Imaging | IBM Watson |
| **Intelligent speech** | iFLYTEK Intelligent Speech | Microsoft Azure Cognitive, Google Cloud ML Service, IBM Watson |
| **Intelligent vision** | SenseTime Intelligent Vision | Amazon Rekognition, Google Cloud Services, IBM Visual Recognition |
| **Smart education** | Squirrel AI Intelligent Adaptive Leaning | Knewton |
| **Smart retail** | JDAI | Google Cloud for Retail |

Source: Corporate websites, Deloitte Research

The Ministry of Science and Technology and other government bodies announced the first new-generation open AI platforms at the national level after full research and surveys in 2017. The four platforms for self-driving, city brain, medical imaging and intelligent speech were established with the support of Baidu, Alibaba Cloud, Tencent and iFLYTEK. The Ministry of Science and Technology established the first open AI platforms for intelligent vision at the national level with the help of SenseTime in September 2018. Multiple areas including education, retail and government affairs have established open application platforms driven by core technologies:

- **National open autonomous driving platform**
  National open autonomous driving platform provides open, complete and safe hardware and software as well as services for developers to support their establishment of comprehensive autonomous driving systems, based on Baidu Apollo. In August 2019, Baidu's Apollo self-driving cars demonstrated how L3 and L4 models run in high-speed driving scenarios under cooperative vehicle-infrastructure system (CVIS) for the first time in China, through road testing in Changsha. Up to this point, Baidu had finished over 2 million kilometers L4 autonomous driving test on urban roads.

  Baidu's open platform Apollo has established alliances with over 120 organizations across the industrial chain, including OEMs, parts manufacturers, travel service providers, startups, telecom companies, universities and colleges, and local governments. King Long Motor, BMW and Daimler are engaged in cooperation with Apollo. In addition, Apollo has been used for commercial operation in Xiongan New Area of Beijing, Shenzhen, Pingtan County of Fujian, Wuhan of Hubei and Kyoto of Japan, etc.

- **Open and innovative city brain platform**
  AI-based national open city brain platform has been established with the support of Alibaba Cloud. Modelled after city brain systems, this platform provides open ecosystems with diverse elements for AI application in city security governance, public services and other sectors, supporting the innovative application of new-generation AI technologies in different areas of an intelligent society. Algorithm system platforms can optimize large-scale vision computing platforms; round-the-clock and full-coverage automatic traffic patrol alarm systems can detect all traffic accidents in the city in a real-time manner, presenting an accuracy rate of over 95%; traffic prediction systems can predict smooth flow of traffic across the city timely and accurately, based on historical and real-time video data.

  The open platform is mainly applied in a city's traffic sector for the establishment of unified data integration engines, traffic prediction systems, mass data integration control engines and general traffic condition detecting systems. The platform has provided more than 1,000 cloud servers for local governments of Hangzhou, Quzhou, Shanghai, Jiaxing, Macau and Kuala Lumpur, etc. to support real-time analysis and processing of mass multi-channel video data. City brain algorithm teams provide public security, traffic and municipal administration organizations with algorithms in image detection, identification and segmentation, etc. Take Hangzhou's city brain as an example, Enjoyor and SUPCON cooperate to calculate panoramic data of videos, coils, microwave and internet timely, integrating the traffic management and control experience of traffic police with the traffic light timing strategy of city brain. Practices in Hangzhou's urban area, Xiaoshan District and Yuhang District have achieved favorable results.

- **Open and innovative medical imaging platform**

  Tencent Miying, an AI medical imaging platform, has been applied in the diagnosis of multiple diseases, from early diagnosis of esophageal cancer to the diagnosis of lung cancer, diabetic retinopathy, breast cancer, colorectal cancer and cervical cancer, etc. AI diagnosis platform is able to assist doctors in the diagnosis and prediction of more than 700 diseases and has been used in 90% high-frequency diagnosis of the outpatient service.

  Tencent has established an open and innovative medical imaging platform, which integrates participants from various sectors including medical care institutions, scientific research organizations, equipment manufacturers, AI startups, information technology solution providers, universities and colleges, and pro bono organizations. The platform connects core players in innovation and entrepreneurship, cooperation across the industrial chain, scientific research, and public welfare, aiming to drive the implementation of national AI strategies in healthcare. So far, open medical imaging platforms based on Tencent Miying have established cooperation relationships with more than 100 hospitals, playing an important role as evidenced by the practices of interpreting 106 million radiographs, serving 950,000 patients, identifying 130,000 high-risk lesions and analyzing 6.14 million medical records.

- **Open and innovative intelligent speech platform**

  National open intelligent speech platform is set up mainly based on iFLYTEK's speech platform technology. Related AI research and data centers have been established. As of late October 2018, a complete AI industrial chain covering technology research, basic platforms, IoT and intelligent hardware, etc. had taken shape, with over 860,000 teams engaged in platform development and more than 200 companies participating in the platform. Six intelligent speech related national standards have been approved and released, as a part of proprietary intellectual property rights and standards system for the development of intelligent speech technology and relevant application, creating a sustainable innovation mechanism facilitating cooperation among enterprises, universities and research institutions.

  iFLYTEK's key intelligent speech technologies involve speech synthesis, speech recognition, machine translation, speech assessment and cognitive intelligence. In open source, the platform shares core technology development interfaces and cloud online service capabilities. The industrial chain service platform integrates solution providers, industrial design resource, sales channels and production supply chain resources, etc. Seven business incubators covering over 100,000 square meters have been launched in Hefei, Changchun, Luoyang, Xi'an, Chongqing, Tianjin and Suzhou, based on the support of developer service communities and local governments. These incubators have attracted more than 500 development teams and companies in intelligent speech and AI.

- **Open and innovative intelligent vision platform**

  National open intelligent vision platform is established based on SenseTime's vison platform technologies. SenseTime's open intelligent vision platform is committed to the research and development of core technologies related to intelligent vision tool chain, fundamental intelligent vision technology breakthrough and establishment of an international intelligent vision talent system, with the aim to drive China's development of AI application in vision sector. SenseTime's core technologies include face detection and tracking, facial feature points localization, facial authentication and scene recognition, etc.

  SenseTime's platforms in video content audit, city-level visual analysis, driver monitoring system and augmented reality provide solutions for various scenarios including security, commerce and finance. Public security system checks the identity of suspects through view information research and judgment system. Facial recognition is applied in self-service store and payment verification, based on cooperation with large retailers. Employment of identify authentication technology in financial sector leads to lower financial risks and better customer experience.

- **Open intelligent adaptive education platform**
  The State Council proposes to establish intelligent schools and platforms integrating teaching, management and service; and leverage modern technologies to drive the reform of talent development model, combining mass education with personalized development in a reasonable manner in *China's Education Modernization 2035*. Education is technologically sophisticated in AI application, having accumulated mass and scattered resources in technology, content and data. AI-based education companies are exploring open education platforms to accelerate industrial development and support China in realizing AI development objectives. Pioneers such as Yixue Education—Squirrel AI are taking the lead in developing intelligent adaptive education platforms.

  The five national open AI platforms and intelligent adaptive education platform mentioned above intend to connect players across the industrial chain. In education industry, intelligent adaptive education technology can provide personalized education solutions to support platforms in improving intelligent adaptive capabilities, with larger amount of data and more comprehensive student profiles. Crowdsourcing partners can provide platforms with more extensive and reliable contents and diverse personalization abilities, through optimization and innovative transformation of contents, teaching logic and user experience. Intelligent adaptive capability access partners can help platforms optimize intelligent adaptive algorithm engines for more inclusive application and higher efficiency.

## 2.3 Human vs. machine

AI allows machines to perform tasks including cognition, recognition, analysis and decision making that are traditionally performed by human, exploring how to enable computers to simulate human in performing some thinking and intelligent behaviors. It mainly studies how to allow computers to perform intelligent behaviors, produce computers with the ability to think as human and realize more sophisticated computer application. AI involves many different subjects including computer science, psychology, philosophy and linguistics. The ability to perform tasks as or better than human is an important indicator of AI development.

Compared with human, AI can be classified into weak AI, strong AI and super AI. The development of AI application varies in different sectors, mainly affected by the following key factors:

- **Clarity of rules and assessment standards:** Some activities such as chess and cards games can be assessed by computers according to simple, clear and quantitative criteria.
- **Frequency of exceptional cases:** Processing in typical scenarios and processing in scenarios with exceptional cases, such as facial recognition and autonomous driving. Machines have advantages in handling uncertainties.
- **Size of training data:** Many fields are at the initial stage in training data accumulation. For example, the accumulation of labelled data in supervised learning requires large amount of human labor and cost input, significantly restricting the development of AI application in relevant fields.
- **External factors:** The development of AI application is slow in some fields, subject to policy factors. For example, data in some sectors such as healthcare are exclusively owned by a few organizations, which proves to be obstacles for data sharing.

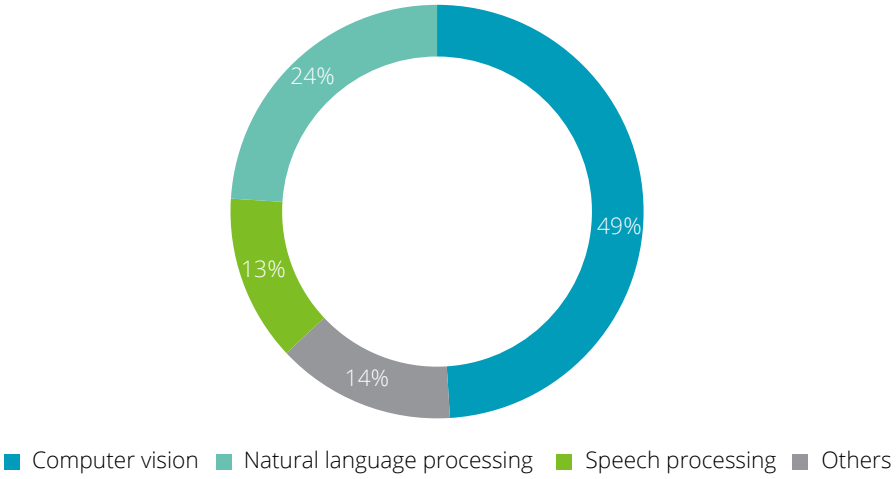
### Stage 1: AI technologies better than human in recent years

Application of AI technologies from IBM DeepBlue to OpenAI Five in various sectors such as chess and cards, debate, e-sports and even healthcare and education proves that the battle of "human vs. machine" can test a company's technology capabilities and draw more public attention to AI, thus is playing an important role in assessing the development of AI application in each sector.

In 2015, Microsoft and Google developed image recognition technologies which are better than human skills. Baidu's speech recognition technology is also better than related human ability. According to the statistics of World Intellectual Property Organization (WIPO), among all AI application technologies, computer vision ranked No.1 in terms of patent filings from 2013 to 2016, accounting for 49% of total filings with an increase of 24%, followed by natural language processing (14%) and speech processing (13%). Biometrics and scene understanding, two sub-categories under computer vision, ranked among the top with a growth of 31% and 28%. Speech processing technologies speech recognition and speaker recognition both realized a growth of 12%. In education, intelligent adaptive education performs the same as or even better than human teachers in terms of teaching effectiveness, user experience and testing scores. Domestic and overseas intelligent adaptive education companies including Knewton, Yixue Education—Squirrel AI, Realizeit and ALEKS have compared the effect of AI education technologies and human teachers through experimental practices in the trend of "human vs. machine".

AlphaGo is an AI-based Go program operating with deep learning, and is the first AI robot to defeat a human Go professional and the first to defeat a Go world champion. In March 2016, AlphaGo played against Lee Sedol, Go world champion and 9-dan professional, and won 4-1. From the end of 2016 to early 2017, the program registered an account named "Master" at a Chinese Go website and played games with dozens of Go master-hands from China, Japan and South Korea, recoding 60 consecutive wins and 0 losses. In the Future of Go Summit held in Wuzhen in May 2017, AlphaGo played three games with Ke Jie, the world No.1 ranked champion, and won 3-0. The emergence of AlphaGo is pushing the battle of man versus machine to a whole new era.

**Figure 2-3: Percentage of AI application technologies in terms of patent filings across the world (as of 1H 2018)**




Source: WIPO, Deloitte Research

- **Computer vision**
  Computer vision is a combination of eyes and brain, involving images, perception and understanding. It has surpassed human in its capabilities, especially in facial recognition and image classification. Machines are more acute in perception than human eyes, being able to gain more information with higher accuracy of image recognition. In addition, machines can stimulate human in performing some creative activities. Machines recorded an approximate image recognition error rate of 2.9% in ILSVRC 2016, much lower than 5.1% of human beings, with good performance throughout object detection (recognition), object positioning and detection of objects in videos. Deep learning-based computer vision has exceeded human, as it is simply driven by large amount of data rather than human will. Machine vision performs understanding activities based on data, in a way different from that of human beings.

- **Speech recognition**
  Speech recognition was created by Bell Labs in the 1950s. Carnegie Mellon University launched a speaker-independent, large-vocabulary and continuous-speech recognition system in late 1980s. It is worth noting that speech recognition systems that can recognize Chinese better than people came into being earlier than those that apply to English. Baidu announced in 2015 that their speech recognition system can recognize Chinese better than human with lower character error rate (CER). YITU's short speech dictation technology realized a CER of 3.71% in December 2018, symbolizing a significant improvement of speech recognition accuracy. Speech recognition technology is improving in accuracy over time. Such machine-perception technology is relatively sophisticated, while machine-cognition semantic understanding is limited by factors including training method, labelled data volume and computational complexity, therefore impeding the development of voice interaction.

### Figure 2-4: Maturity of speech and vision technologies

| Technologies | Maturity | Application scenarios | Representative companies |
|---|---|---|---|
| **Object and scene recognition technology** |  | Security;<br>Autonomous driving;<br>Smart appliances;<br>Drones | Malong Technologies;<br>TuSimple;<br>YITU;<br>DeepGlint |
| **Biometric recognition technology** |  | Photo editing software;<br>Security;<br>Smart appliances | SenseTime;<br>CloudWalk Technology;<br>MEGVII |
| **Optical character recognition technology** |  | Finance;<br>Translation software | DeepGlint；<br>CC Intelligence |
| **Video object extraction and analysis technology** |  | IoT;<br>Security | Malong Technologies;<br>Intellifusion;<br>Hikvision |
| **Speech recognition** |  | Intelligent speakers;<br>Real-time translation | Tecent;<br>Baidu;<br>Sogou;<br>iFLYTEK |
| **Semantic analysis** |  | Mobile search;<br>Intelligent vehicle information systems | Mobvoi;<br>Unisound;<br>iFLYTEK |
| **Voice interaction** |  | Vehicle information systems;<br>Appliances;<br>Robots | SinoVoice;<br>AISpeech |

Source: Publically available information, Deloitte Research

- **AI-based education**
  Compared with games which have clear systems and complete data such as go, educational system is far more complex, involving various subjects including pedagogy, psychology and cognitive science. Intelligent adaptive learning combines AI, data mining, cognitive science, pedagogy, psychology, behavioral science and computer science, allowing adaptive learning system to simulate human teachers to some extent and adjust learning contents based on special teaching strategies in accordance with students' learning objectives, learning behaviors, preference and status, thereby to realize personalized education. AI-based adaptive education provides students with personalized tutoring and higher learning efficiency, imitating experienced human teachers with good teaching methods. Machine learning technology enables adaptive education to adjust students' learning contents and paths on a real-time basis, rather than organize unified learning according to syllabus or teachers' arrangement in a traditional way.

  The development of AI application in education is likely to address social problems resulted from uneven distribution of educational resources. Apart from AI application in education and related supporting technologies, extensive adoption of AI-based education also requires integration of quality educational resources and establishment of data pools by enterprises, algorithm advantages, large sample size, and market recognition of intelligent adaptive learning based on coordination among the government, schools and teachers.

**Phase II: Technologies to be well above human average in the next two to over ten years**

AI capabilities are improving in separate technologies such as speech and visual recognition, and applied to numerous commercial areas rapidly. While with the rapid growth of AI in these commercial areas involving increasingly complex sectors and scopes, separate technology solutions can no longer meet the application needs of industries. Application technologies, including autonomous driving and intelligent healthcare, involve in several AI application technology sectors.

AI technologies has a long way to go in commercial application from academic research, patent application to industry application. The initial focus of patent application is to develop technical solutions for industrial application, often with a lag of about ten years behind scientific publications. Statistics from the World Intellectual Property Organization find a decline in scientific papers to patent publications, indicating a stronger interest of industries in the practical use of AI technologies.

Transportation has been the fastest growing sector in the application of AI technologies from 2006 to 2019. The application of AI in transportation only accounted for 20% of total patent applications in 2006 while the figure reached one third as of 2019. In 2019, autonomous driving and healthcare are two hot AI technologies as they can dramatically improve social resource distribution and change people's life style. However due to technical barriers, they are not fully applied for commercial uses and still on trial.

- **A long to go for fully autonomous driving**
  Autonomous driving is ultimately aimed to realize truly autonomous driving and enable passengers to do other things with an eye on roads. But this requires advancements both in hardware and software. In terms of hardware, LiDAR is likely to cost tens of thousands of dollars leading to higher costs for a large scale deployment. As for software, engineers need to find an approach to equip AI with the ability to arrange and differentiate various objects. Autonomous driving relies on the collaboration of AI, visual computing, radar, monitoring devices and global positioning systems.

**Figure 2-5: Distribution of autonomous driving technologies**

| Automotive technology | Segment technologies | Representative companies | Constraints | Estimated maturity |
|---|---|---|---|---|
| **Finished vehicle** | Controls integration<br>Unmanned vehicle | Bosch<br>Continental<br>WayMo<br>Baidu<br>Tesla<br>Nissan | • Rule: Lack of depth (deep dive into specific technologies in every scenario)<br>• Specialty: Lack of width (various scenarios in large spans)<br>• Training data: Low statistical confidence of data; few mileage samples | Over ten years is required to reach L4-L5 |
| **Sensing** | Video camera<br>Ultrasonic radar<br>Millimeter-wave radar<br>LiDAR | OV<br>O-film<br>DENSO<br>Glarun Technology<br>Bosch<br>Continental<br>Veldyne<br>IBEO | | |
| **Positioning** | High precision map | Google<br>Baidu<br>NavInfo<br>Beidou<br>Galileo<br>Glonass | | |
| **Underlying support** | ADAS algorithm<br>Automotive chip<br>CMOS sensor | Mobileye<br>Zongmu Technology<br>NVIDIA<br>Sony<br>Samsung | | |

Source: Publicly available information, Deloitte Research

Measured by the clarity of rules and evaluation methods, the frequency of special cases and the scale of training data, autonomous driving has not yet reached or gone beyond human capabilities as image recognition and speech processing have done, nor it can make judgement like human.

'Before the fully autonomous driving market matures (L4-L5), the industry must start with three capabilities. Firstly, cars must have the sensing capability of environmental model 360 awareness, equipped with LiDAR, optical sensor and millimeter-wave radar, etc. Secondly, cars must be equipped with high-resolution maps with localization at high accuracy of less than 10 cm. And thirdly, the market must make driving or yield rules that are perceived and accepted by cars and pedestrians. Meanwhile, cars must be deployed with sensing, reasoning and decision-making abilities similar to human as human are likely to violate traffic regulations, hesitate or go forward or back.' Besides, autonomous driving should not grow along with technical advancement, but it requires laws and regulations, awareness or even the overall supporting facilities such as insurance and infrastructure built by governments.

As a result, autonomous cars have a long way to replace other cars, during which the co-existence of autonomous cars and human drivers should be prioritized.

- **Lack of practicable rules and standards for the application of AI healthcare**
  Measured by the clarity of rules and evaluation methods, the frequency of special cases and the scale of training data, AI healthcare is still at the mid-stage and has a long way to go to fully replace doctors. In intelligent diagnosis as an example, there are certain issues and challenges in medical liability concerning AI's assistance to diagnosis. Users may leave out or even incorrectly express their chief complaints via virtual medical assistants, leading to the discrepancy of suggestions generated by virtual assistants and users' diseases.

**Figure 2-6: Technologies involved in AI healthcare**

| Application scenarios | Underlying technologies | Representative companies | Constraints | Estimated maturity |
|---|---|---|---|---|
| **Medical imaging** | Computer vision | Infervision<br>Yidu Cloud | • Rule and specialty: High misdiagnosis rate, such as the average misdiagnosis rate due to imaging analysis reaching 27.8%<br>• Lack of training data | More than ten years |
| **Electronic medical record (EMR)** | Natural language processing<br>Speech recognition | Unisound<br>CTME<br>iFLYTEK | • Low market acceptance | Two to five years |
| **Assisted diagnosis and treatment** | Robot | TINAVI<br>SMAROBOT<br>SIASUN Robot | • Various specialties;<br>• Limited by market regulation, such as about 97 months is required from molecule discovery to FDA approval | Two to five years |
| **Disease risk prediction** | Machine learning | Berry Genomics<br>Precision Genomic<br>BGI Genomics | - | In the near future |
| **Health management** | Computer vision | MORE HEALTH<br>Airdoc<br>iCarbonX | - | In the near future |
| **Drug discovery** | Machine learning | Cipher Gene<br>3D Medicines<br>Ribo | • Existing rules and specialties<br>• Limited by market regulation | Ten years |

Source: Publicly available information, Deloitte Research

In terms of rules and evaluation methods, the absence of medical information standards presents challenges for the application of AI in medical sector. AI is a tool focusing on mathematics and logic, requiring higher accuracy and standardization of contents. As for marking lesions in medical images, for example, even doctors from the same department have various marking methods. And regarding medical records, it is challenging to synchronize patients' EMRs accurately and names of various diseases vary with different doctors on a geographic basis.

Countries keep a sharp hold on the market access mechanism for new technologies due to complex diseases and higher frequency of special cases as well as high relevance with people's livelihood and life-threatening errors. Currently, regulators prohibit virtual assistant software from generating diagnosis suggestions on any diseases, only simple inquiry and advisory services for users' health issues allowed. Regulators in China tightly control the review and approval of diagnosis functions provided by AI technologies. According to the classification rules in the new edition of CFDA's *Medical Device Classification Catalogue in 2017*, for diagnosis software which provides diagnosis suggestions based on algorithms, it can apply for certification of class II medical devices as it cannot directly provide diagnoses if only with assistant diagnosis functions. For those that can automatically identify lesions and provide clear diagnosis tips, they must apply for clinical trial certifications in line with requirements for class III medical devices.

Measured by the scale of training data, a number of problems can be found with medical data. Despite of a large volume of medical data in China, data specifically related to one certain category of medical problems are of low volume and quality. In medical imaging, for instance, relevant data can be provided for machine learning only after clinical seasoned doctors mark the data, but such quality and marked data resources are limited. Enjoying a majority of imaging data and experienced doctors, 3A-grade hospitals are most capable of helping AI companies develop effective models.

**Phase III: 2099 the age of strong AI?**

Strong AI is a type of artificial intelligence equivalent to human intelligence in all aspects, enabling robots to fully possess abilities as human have rather than being limited within a certain sector. Strong AI can think, plan, solve problems, do abstract thinking, understand complex ideas, and learn fast and from lessons. Some think that strong AI will appear if it can mimic the human brain and replicate all human brain neurons and synapses of the same magnitude.

We are now in the stage of weak AI which helps reduce human's intellectual work, similar to advanced bionics. Both AlphaGo and robots capable of writing news releases or novels are still weak AI, with limited capabilities better human. Data and computing power are of undoubtedly great significance in the era of weak AI, pushing forward the commercial use of AI. And the two elements are still the most important in the times of strong AI. Besides, researches of tech giants marked by Google and IBM on quantum computing is a strong driver for human to enter the age of strong AI.

**Figure 2-7: Representative companies and research of strong AI**

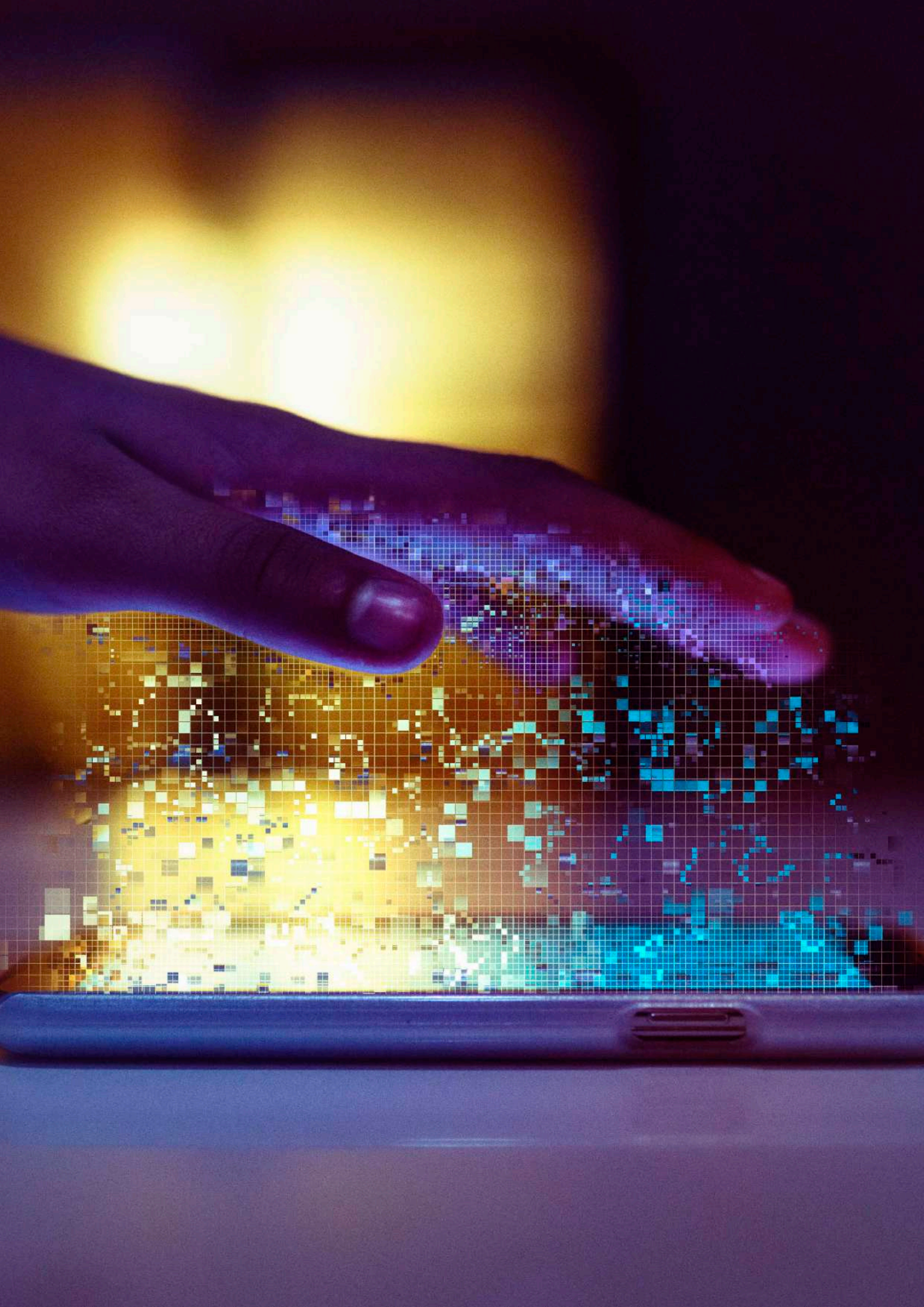
| Representative companies | Research orientation | Milestones |
|---|---|---|
| **IBM** | Cognitive computing<br>Pan man-machine interaction | IBM Debater<br>Watson |
| **Google** | Systems neuroscience methodology<br>Pan man-machine interaction | Google Assistant<br>PathNet<br>AutoML project |
| **Microsoft** | Pan man-machine interaction | Cortana |
| **OpenAI** | Deep reinforcement learning | Writing AI<br>Spinning Up program |

Source: Publicly available information, Deloitte Research

As stated in the *Architects of Intelligence*, based on the average estimate of researchers and entrepreneurs working in AI today, including DeepMind CEO Demis Hassabis, Google AI Chief Jeff Dean and Stanford AI director Li Feifei, the era of strong AI will come by 2099.

Discrepancies from these simple estimates indicate that we have a long way to go to achieve strong AI. However, many research teams from large tech players and small companies are making their contributions to building strong AI. Google's DeepMind and Google Research take specific measures, while PathNet (a solution of training large general-purpose neural networks) and evolutionary architecture search AutoML (a method of finding good neural network structures for image classification).

Additionally, OpenAI, co-founded by Tesla's founder Elon Musk and partly supported by Amazon Web Services, is doing a great deal of research aimed at strong AI. OpenAI also creates two special tasks: Gym and Universe to test the skills of strong AI that are under development.



# 3. China's position in global AI sector

This AI wave is featured by the move of lab findings towards commercial application, mainly driven by the significant enhancement of computing power, a wide range of policy supports, highly frequent large investments and increasingly identified user demands. The AI industry is fast growing in China where exist over 4,000 AI companies in 2019, ranking the second in the world and enjoying certain advantages in data and application. However, there is still a certain gap between China with regions leading the world in several aspects including basic research, chip and talent.

**Figure 3-1: Comparison of AI in China and regions leading the world**

| | | China | Regions leading the world |
|---|---|---|---|
| **Data** | | • Possess the large number of mobile internet users in the world<br>• China has introduced a national standard entitled Information Security Technology - Personal Information Security Specifications, lower stringency than GDPR | • Users focus more on personal privacy<br>• European governments introduced GDPR to separate the right of use and ownership of data in policy terms while the U.S. may come hot on the heels |
| **Software** | **Chip** | • China possesses almost half of the market value, yet relying heavily on imports in high-end chips<br>• Lagging behind in semiconductor equipment, materials and manufacturing | • Japan is an important producer of semiconductor materials, high-end equipment and special semiconductors<br>• South Korea takes an absolute lead in high-bandwidth memory and dynamic random access memory (D-RAM) |
| | **Robot** | • A large gap with advanced world level<br>• Lack of originality | • Japan still tops the world in robotics |
| **Technology** | **NLP** | • 92 NLP companies<br>• RMB12.236 billion raised<br>• 6,600 employees | • 252 companies in the U.S.<br>• RMB13.467 billion raised in the U.S.<br>• 20,200 employees in the U.S. |
| | **Computer vision** | • 146 companies<br>• RMB15.83 billion raised<br>• 1,510 employees | • 190 companies in the U.S.<br>• RMB7.32 billion raised in the U.S.<br>• 4,335 employees in the U.S. |
| | **Speech recognition** | • 36 companies<br>• RMB3.087 billion raised | • 24 companies in the U.S.<br>• RMB1.931 billion raised in the U.S. |
| **Application** | **Autonomous driving** | • China is catching up in auto sensing tech, AI hardware and software, connectivity V2X and autonomous driving testing | • The U.S. has a solid technical base |
| | **AI education** | • China has just started the application of AI technologies which is still in its infancy mainly focusing on ToC. | • The application of AI technologies in education has grown earlier abroad<br>• AI-based educational products penetrate deeper in Europe and the U.S. |

Source: Oxford's Future of Humanity Institute, Tencent Research Institute, Deloitte Research

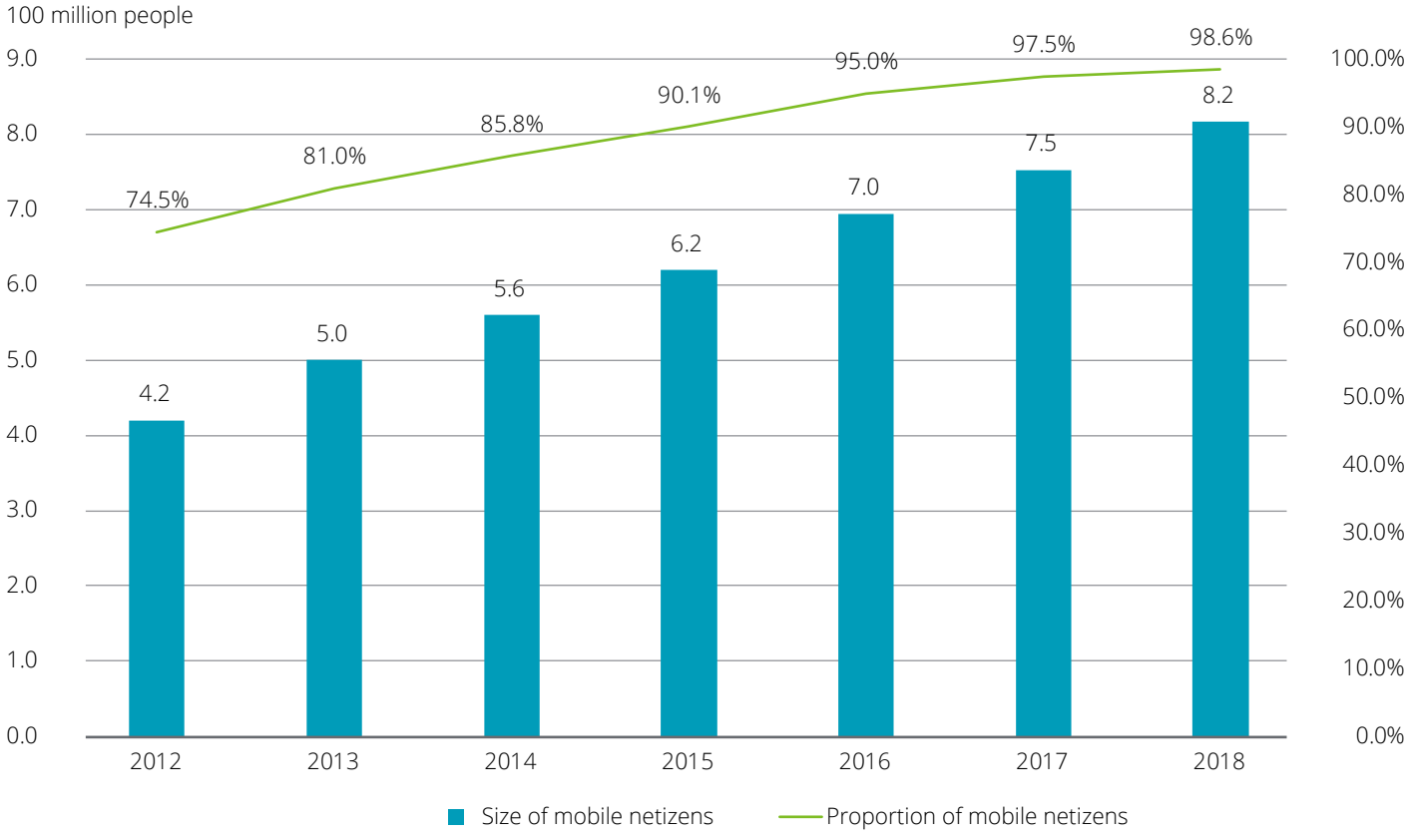
### 3.1 China has larger volumes of data and more diversified environment for using data

AI technologies are evolving on the basis of massive data. In the mobile Internet era which has arrived, data generated from mobile devices are far more important than PC Internet.

In terms of the volume of data, China has the largest number of netizens in the world, reaching 829 million at the end of 2018 with the penetration rate of 59.6%. The number of mobile netizens exceeds 800 million for the first time, accounting for 98.6% of the total netizen population[21]. The enormous quantity of netizens means that the data Chinese companies can access to are more complex and multiple-dimensional and serve as a solid foundation for the algorithm upgrade of AI technologies and the expansion of application scenarios.

In addition to data, governments' regulations on private data also have a great impact on the potential for companies to use data. European governments have introduced General Data Protection Regulation (GDPR) as the strictest policy to protect user privacy in the world, providing users with the claim of right on their personal data that users have the right to acquire and revise their personal data and decide who can use them[22]. China has also published a national standard entitled Information Security Technology - Personal Information Security Specifications, but with lower stringency than GDPR. For example, apart from employers, physiological state, mental state, economic status and social status are also included in the identity defined by the EU.

**Figure 3-2: Size and proportion of Chinese mobile netizens**




Source: CNNIC, Deloitte Research

21. *The 43th Statistical Report on Internet Development in China*, CNNIC, http://www.cnnic.net.cn/hlwfzyj/hlwxzbg/hlwtjbg/201701/t20170122_66437.htm
22. *Titans of Tech: Europe's Flagship Companies*, The Economist, April 2019

### 3.2 China is in the highest demand on chip in the world yet relying heavily on imported high-end chips

AI framework can be broadly divided into three layers. The infrastructure layer includes core AI chip and big data, which is the base for sensing and cognitive computing power at the technical layer. The application layer is at the top, providing autonomous driving, intelligent robot, smart security and virtual assistant services. As the core of the AI technical chain, AI chip is essential for AI algorithm processing, especially for deep neural networks. Today, the integrated circuit chips imported by China from the U.S. values over USD200 billion, far higher than crude oil imports.

In East Asia, Japan has long been the leader in semiconductor R&D and material industries, marked by semiconductor titans including Toshiba, Sony and Renesas Electronics. South Korea and Taiwan have certain advantages in memory and foundry services. South Korea is leading in D-RAM and NAND flash memory with many top semiconductor companies including Samsung and SK Hynix, largely powered by governmental support. The requirement of core technical competency in NAND memory market makes it challenging for new entrants to compete in the market. Taiwan has become the globally leading semiconductor foundry service provider where the foundry industry is dominated by two contract manufacturers: TSMC and UMC. Semiconductor foundry is an important pillar of information technology industry.

China's semiconductor industry is thriving at a double-digit rate. AI chip market sees active capital raising activities and an increasing number of M&As. A typical example is the global giant Xilinx's acquisition of DeePhi Tech, a start-up specializing in machine learning, deep compression, pruning and system-level optimization for neural networks. Tech giants led by Alibaba, Baidu and Huawei have stepped into this battlefield. It is worth noting that Huawei has started AI chip competition in smartphone sector. And Chinese mainland is eating into Taiwan's semiconductor market shares. Moreover, the growing Chinese mainland market will be a commercial channel for integrated circuit design industry and Chinese mainland companies will continue to invest in Taiwan's semiconductor industry. However, Chinese semiconductor producers have significantly improved their competitiveness in recent years while the key parts are still largely imported from western countries with the self-sufficiency ratio lower than 20%. Chinese government is greatly concerned about this issue and released several favorable polices to support the growth of the semiconductor industry.

### 3.3 Chinese robot companies are growing fast with greater efforts in developing key parts and technologies domestically

Robot R&D and application is an important index for measuring the technological development level of one country and the future economic growth will be highly relevant with the robot industry to a large extent. As an important part of building advanced manufacturing industry, robots, both industrial robots for production activities in the industry sector and service robots participating in human's daily life, are of great significance in seeking new growth engines. With strong support of funds and policies, China's robot industry is growing rapidly and continues to top the world in terms of growth rate. The market exceeded USD8.74 billion in 2018[23] at the average growth rate of 29.7% from 2013 to 2018.

Key robot components are still largely imported, including high-precision reducers, controllers and servo motors. Japanese companies dominate more than half of the global high-precision reducer market. In terms of software, China has certain skills in control algorithm and secondary development yet with a gap with foreign markets in stability, responsiveness and accessibility.

Additionally, in terms of the application scenarios of robots:

In industrial robots, several local robot companies, including Shenyang SIASUN, EFORT, GSK, Harbin Boshi, STEP, ESTUN and JEE, have grown fast. In the past years, domestic robot companies have initiated outbound M&As to acquire overseas advanced technologies and expand foreign markets. ESTUN, EFFORT and Wanfeng Technology have acquired European and American companies. Among three core robot components, controllers and servers are increasingly made in China but reducers are still imported. There is a large gap of domestically made reducers in product performance and precision though in line with consistent design principles. Global service robots are on the rise. Despite of a late start, China is slightly inferior to the global advanced level, even leading in some key technologies. Tech giants including BATJ step in the market backed by their strong technical capabilities while traditional home appliance companies, e.g. Haier, are actively marching into home service robots, and research institutions, such as Harbin Institute of Technology, are converting research results through cooperation with companies.

Special robot market is in its infancy, mainly covering vertical sectors like firefighting. Companies have certain independence and made breakthroughs in key technologies such as high-precision positioning and navigation and obstacle avoidance.

### 3.4 The U.S. has solid strengths in AI's underlying technology while China is better in speech recognition technology

**Natural language processing (NLP):**

China is catching up with the US

NLP technology is able to change the way for human to interact with machines. Massive dark data that are undiscovered in business data sector cannot be applied by means of current technologies, including unstructured data such as short message, files, emails, videos, speeches and pictures. NLP technology will play an important role in commerce.

China is catching up with the US in terms of natural language processing (NLP). Enterprises represented by Alibaba and Baidu has taken the lead in NLP. In particular, Baidu's leading language and knowledge technologies are widely applied in intelligent search, deep Q&A, dialogue system, intelligent writing, machine translation and many other fields.

23. *Report on the Development of China's Robot Industry (2018)* (《中国机器人产业发展报告（2018）》), Chinese Institute of Electronics

**China is superior in speech recognition**

Speech recognition technology can be widely applied in such scenarios as TVs, mobile phones, call centers and smart homes. In this aspect, the average recognition accuracy rate of main platforms, including Baidu, iFLYTEK and Sogou, reaches over 97%. Alibaba's speech AI technology is superior to Google and is named by MIT as one of 10 Breakthrough Technologies 2019[24] . And this technology has been penetrated in many scenarios, such as express delivery, customer service and train ticket purchase. During the 2018 11.11 Global Shopping Festival, Ali Xiaomi handled 98% of customer enquiries from the whole platform, equivalent to one-day workload of 700,000 human customer service staff.

**Computer vision: A large gap in basic algorithms**

Computer vision has long been one of hot AI technologies. People's daily life has been surrounded by buildings' access control, traffic cameras and banks' security cameras. Ubiquitous cameras, integrated with facial recognition technology, magnify existing security effects and monitor everyone's behaviour.

From application layer perspective, there is little difference between China and the U.S. and even China is expected to overtake the U.S. in facial recognition technology. But there is a large gap in basic algorithms between the two countries. China has about 146 companies mostly engaged in the application, including HIKVISION while the U.S. has about 190 companies. China has 1,510 practitioners while the U.S. has more than 4,000[25] .

## 3.5 China is catching up in application

**Autonomous driving: Solid technical base puts the U.S. ahead of China**

Autonomous driving involves technologies including auto sensing technology, AI hardware and software, V2X and autonomous driving testing. Building on governmental support and long established technical base, the U.S. is widening the technical gap with China in sensor technology and AI hardware and software. But Chinese tech giants and research institutes and universities are driving China to catch up in the two areas.

China is almost comparable to the U.S. in connectivity technology and autonomous driving testing. Huawei's 5G technology will provide world-class communication support for connectivity V2X. And Huawei has cooperated with domestic and foreign carmakers in testing. In autonomous driving testing, Beijing, Shanghai, Shenzhen and Chongqing have issued self-driving vehicle testing licenses and provided testing venues for tech giants (e.g. Baidu), who join hands with domestic carmakers such as BAIC and BYD.


24. 10 Breakthrough Technologies 2018, MIT
25. *China vs. U.S.: Battling to become world's first AI superpower,* Tencent Research Institute

**Figure 3-3: China's skill level in autonomous driving**


Source: Publicly available information, Deloitte Research

**AI-based education: Foreign countries are more mature while China has a brighter prospect despite in the early stage.**

The application of AI technologies in education industry started earlier in foreign countries where adaptive technology has emerged early in the 1990s. AI-based education products are widely penetrated in Europe and the U.S. for users at all ages through nearly a decade of growth, involving early childhood education, primary school, secondary school, high school and many subjects in vocational education. It has more application scenarios focusing mainly on To B, including testing agencies, schools and companies. Representative companies can be classified into three categories: online education platforms transforming into intelligent adaptive sector such as Coursera, Khan Academy; intelligent adaptive business units of education groups such as Pearson, Wiley (acquired Knewton), Elsevier, Cengage-McGraw Hill (acquired ALEKS), ETS, ACT and NWEA are offering AI-driven self-adaptive assessment and learning solutions; and intelligent adaptive learning players with efforts to cover five learning parts include large corporations such as IBM Watson Education, Adobe and Dell, as well as specialized companies such as Prowler.io, Knewton, ALEKS and Carnegie Learning. Researches have proven the outstanding results of AI technologies to improve learning performance.

China has just started the application of AI technologies in recent years mainly focusing on To C. But Chinese market has grown fast though in the early stage as Yixue Education—Squirrel AI saw revenue exceeding RMB1billion in 2018 and that of English Liulishuo reached over RMB600 million. Various kinds of education related companies are stepping into AI technology as adaptive learning systems are growing rapidly thanks to China's large population base, education resources shortage and priority on education. Education groups marked by New Oriental and TAL push into adaptive education through investment and self-building. Moreover, there are three other categories of companies including intelligent adaptive platforms, such as the Shanghai-based education company Yixue Education—Squirrel AI, online education companies transforming into intelligent adaptive education and AI companies engaged in intelligent adaptive education. With the unique advantage of going through the whole learning process, intelligent adaptive learning becomes the most widely used technology in all learning parts.

**Figure 3-4: Comparison of AI-based education companies**

| | Foreign | Domestic |
|---|---|---|
| **Business model** | • Mainly focus on To B<br>• Clients include testing agencies, schools, companies | • Mainly focus on To C<br>• Clients include tutorial agencies |
| **Technical level** | • The U.S. and Europe are more mature and achieve notable results<br>• Assist in teaching yet unable to fully replace teachers | • In the early stage of development<br>• Its core goal is at replacing the role of teachers in teaching |
| **Representative company** | • Online education platforms transforming into intelligent adaptive sector (i.e. Coursera, Khan Academy)<br>• Intelligent adaptive business units of education groups (i.e. Pearson, Cengage Learning)<br>• Intelligent adaptive learning players (i.e. Knewton, Aleks) | • Online education platforms transforming into intelligent adaptive sector (i.e. Zuoyebang, Liulishuo,17zuoye)<br>• Intelligent adaptive business units of education groups (i.e. New Oriental, TAL)<br>• Intelligent adaptive learning players (i.e. Squirrel AI)<br>• AI companies (i.e. iFLYTEK) |
| **Prospect** | • Further enhance assistance to teaching<br>• AI is to reshape learning experience and new-type education system is taking shape | • China is seeing fast-growing intelligent adaptive learning systems that is expected to catch up thanks to China's large population base, education resources shortage and priority on education |

Source: Deloitte Research

# 4. AI reshapes every industry

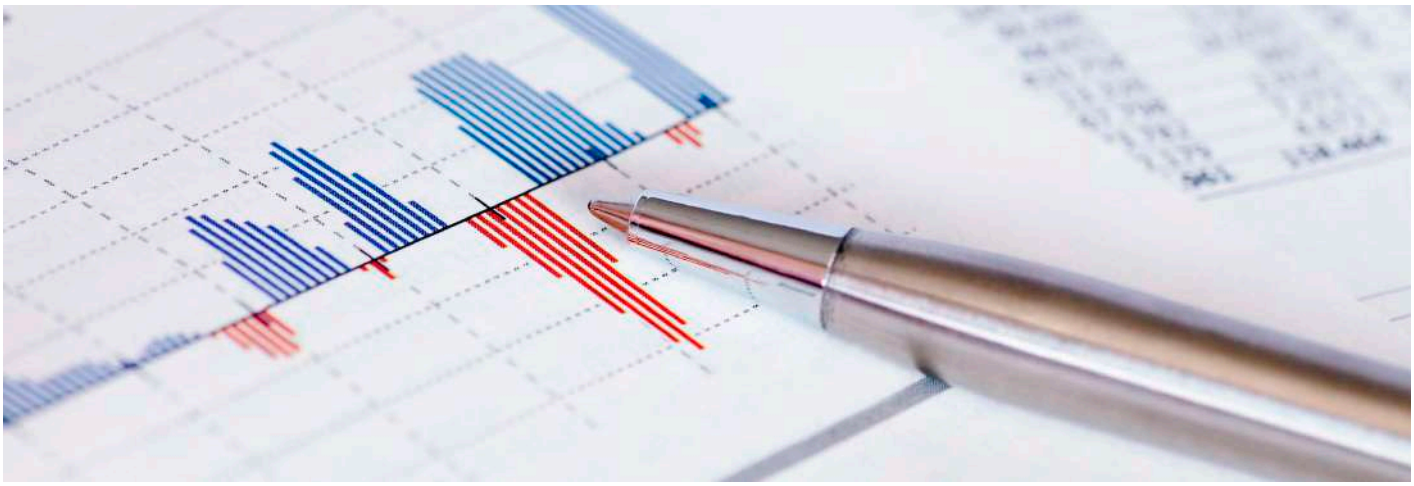
The AI technology saw rapid development during the past five to ten years. Over time, the technology has gradually become known to the public and the pace of the Moore's Law is slowing down. The commercial application of AI has become a key focus. Technology giants increasingly deploy vertical industry application, and start-ups need to find the right entry points and cultivate industry solutions in order to build moats.

Industries and sectors are facing different pain points. For instance, the financial industry is facing cost pressure, product and service homogeneity, and frauds; the healthcare and education industries are facing disproportionate resource allocation. Despite the different pain points, the above issues can be effectively addressed through data collection, processing and analysis. Driven by data, AI can change the industries.

### Figure 4-1: Industry upgrades driven by the AI technology

| Industry | Pain point | Some AI solutions |
|---|---|---|
| **Financial** | • financial institutions face application cost pressure<br>• financial institutions are unable to offer customized products and services to long-tail customers<br>• single credit dimension, with financial risks such as bad debts and frauds | • develop intelligent customer service using technologies such as voice recognition and semantic understanding to resolve users' problems and lower customer service cost<br>• develop intelligent investment advisory using big data and AI to provide personalized services for more customers<br>• build intelligent risk management system by combining AI and big data to enhance risk management capability based on comprehensive evaluation on multi-dimensional data |
| **Healthcare** | • resource allocation cannot keep up with demands as a result of disproportionate healthcare resources<br>• expensive medical expenses and long waiting time<br>• tension between doctors and patients, and misdiagnosis<br>• poor primary healthcare | • intelligent imaging allows quick check of cancer related diseases<br>• health management to change people's health habit from the source |
| **Education** | • disproportionate education resources<br>• teacher-centered rather than student-oriented teaching approach<br>• one-to-one teaching targeting students' specific learning problem is not realistic under the current mode of teaching | • leverages its image and voice recognition functions to analyze problems, and develops customized solutions and effective feedback suitable for learners through deep learning, adaptation and calculation |
| **Autonomous driving** | • frequent car accidents<br>• human attention span is limited<br>• freight transportation cost is high | • with sensors and visual technology, autonomous driving frees the hands of humans; people adopt car-sharing and electrified vehicles; logistics efficiency will be enhanced |
| **Digital government** | • the urban population is expanding and the workload of related public service is huge and complex<br>• crimes and terrorist attacks are not predictable | • leverage technologies including computer vision and machine learning to increase the proportion of self-service<br>• utilize big data to analyze the daily habit of criminal suspects and possible places where they may show up, and leverage computer vision technology to find and arrest criminals |
| **Retail** | • traditional market research methods can hardly reflect the real consumer demands<br>• advertising targets and measure of the advertising impact are inaccurate<br>• consumers are increasingly demanding in terms of in-store experience, payment convenience, and timely delivery | • leverage the machine learning technology to create user profiles and feed appropriate advertisement according to users' preference<br>• leverage machine vision to capture customer behavior and analyze their real needs<br>• leverage technologies including computer vision, voice/ semantic recognition and robotics to enhance consumer experience |
| **Manu-facturing** | • product R&D and design processes are time-consuming and costly<br>• manual processes bring higher error rate and are difficult to trace back<br>• high cost to achieve rapid mass customization with human labor<br>• lack of low-cost labor | • leverage computer vision to identify defective items<br>• human workers are substituted by robots to perform work in dangerous sites |
| **Smart city** | • the progress of urbanization is bringing different degrees of impact on urban economy, resource utilization, living standard, time cost and sustainability; with increasing urbanization and population, urban managers around the world are facing increasingly difficult challenges | • traditional "smart cities" are developing into "super smart cities" covering six aspects to promote the integration of cities |

Source: Deloitte Research



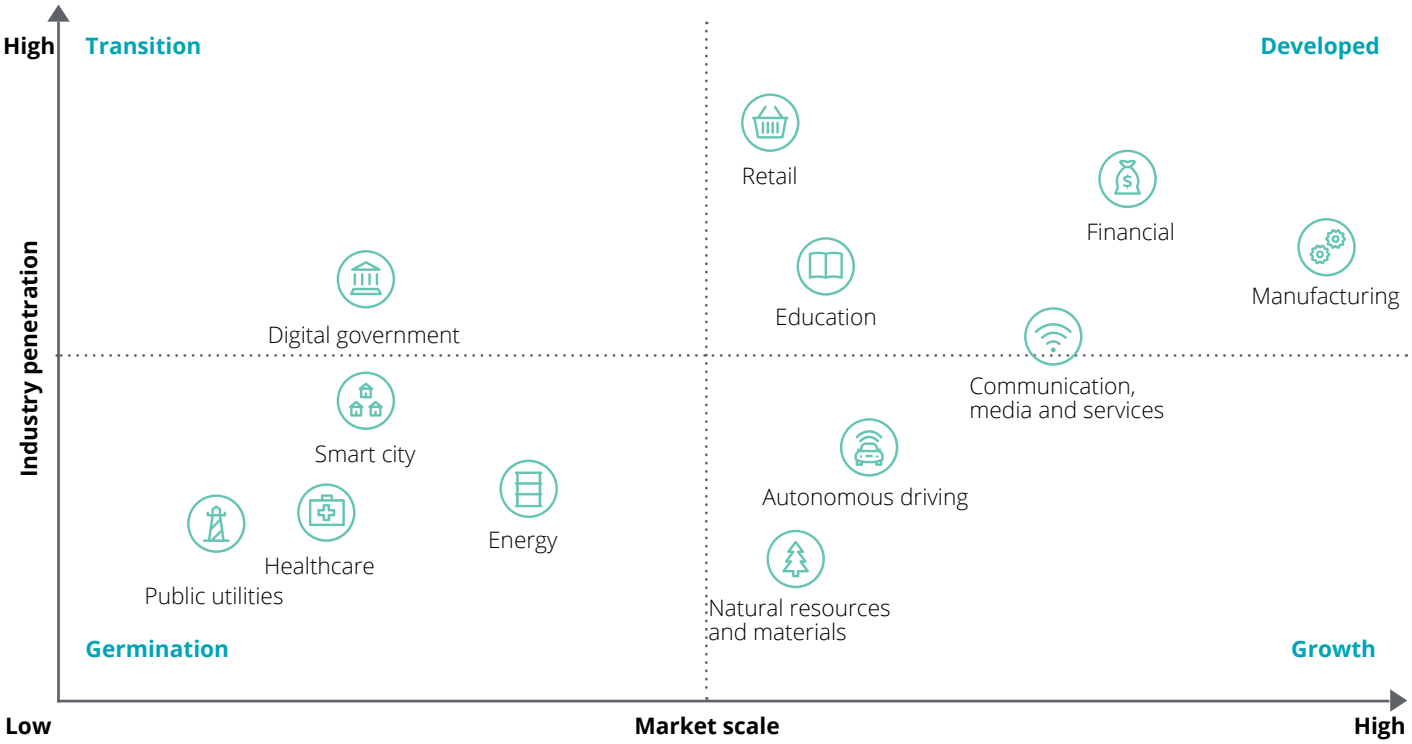
In the financial industry, for example, the AI technology has rapidly changed the key sectors in the traditional financial industry. Amid continuous changes of consumer behaviors and needs, the traditional financial services industry players are facing remodeling of different areas and processes. For instance, with the constant changes of consumer behaviors and preferences, technology–driven precision marketing and feeds enable the provision of customized products and services, enhancing customer stickiness through technology and allowing the inclusion of smaller businesses in the broader ecosystem. In some areas, customer service representatives are gradually replaced by AI robots to provide inquiry services to customers.

In the healthcare sector, amid population aging, increase in the number of people with chronic health problems, shortage of quality healthcare resources and hike in public medical expenses in society, the application of AI in healthcare has brought new development directions and motivation for the current healthcare sector. With the continuous development and implementation of the AI technology in healthcare, the existing complicated medical consultation process will be greatly simplified and better solutions will be provided to the people in a number of aspects including optimization of healthcare resources and improvements in healthcare technologies. AI technology in healthcare has basically covered the four key segments in the healthcare industry, including healthcare, medicine, health insurance, and hospital.

In recent years, the education sector continued to demonstrate unprecedented revolutions through data reconstruction. Unlike traditional education approaches, AI-based education uses data generated from the five key learning processes, namely teaching, learning, practicing, assessing, and testing. It leverages its image and voice recognition functions to analyze problems, and develops customized solutions and effective feedback suitable for learners through deep learning, adaptation and calculation.

The performance of the above industries in the two dimensions namely industry application and market opportunities may be classified into four quadrants. Transition stage means that the level of application of AI in the relevant industry is relatively high, but market opportunities are limited currently and the market scale is expected to expand further in the future. Germination stage indicates that the level of application in the industry and market opportunities are not yet mature, although AI has played certain functions but is still at the initial stage overall speaking. Growth stage means that the level of application in the industry is not sufficient, but application will broaden in the future with more market opportunities. Developed stage means the AI technology has already had a profound impact on such areas with high level of industry application and market opportunities.

**Figure 4-2: Application of AI in different industries**




Source: Deloitte Research

## 4.1 Financial industry: AI enhances the business efficiency of financial businesses and reforms their internal operations

The financial industry is an important application scenario of AI. The application of AI in the financial industry has changed the rules of the financial services industry. Traditional financial institutions and technology companies join hands to build a high-performance and dynamic ecosystem on a broader scale. Participants need to establish extensive interaction with external parties to access the resources they need respectively. Therefore, in the FinTech ecosystem, a profound trust and cooperation relationship will be formed between financial institutions and technology companies, enhancing the business efficiency of financial companies.

Such efficiency enhancements are mainly reflected in three aspects. Firstly, under the traditional financial model, there are often problems such as information asymmetry, high financial risk and high lending cost. The application of innovative technology in the traditional financial business improves the primary service structure of the entire financial industry, thus lowering business cost and enhancing service efficiency. Secondly, with the emergence of various forms of innovative FinTech companies, which are based on innovative technologies and provide customized products and services per customer needs, more long-tail customers barred by traditional financial services are covered, allowing more individuals or SMEs to enjoy more convenient and efficient financial services and covering more customers in terms of volume and range. Thirdly, a wider range and variety of players are attracted to the ecosystem. By evaluating the consumer credit through collection of massive consumption and credit data of consumers, financial risks such as bad debts are lowered. Efficiency enhancements of the three aspects above are mainly reflected in the three areas namely intelligent investment advisory, intelligence customer service and intelligent risk management, which are also the areas with more profound application of the AI technology.

### Intelligent customer service enhances service efficiency

Intelligent customer service refers to the capability to answer simple questions of users, and resolve users' questions related to products or services through human-machine interaction. The level of maturity of NLP is relatively low among other types of AI technologies, but it plays significant value in customer service. High training cost, difficulty in aligning service outcome, and high turnover are issues with human customer service representatives. Based on big data, cloud, and AI in particular, intelligent customer service accelerates the intelligentization of customer service of businesses. Knowledge maps are leveraged to answer simple and repetitive questions, thus reducing the use of human customer service representatives and enhancing the efficiency and outcome of customer service. Customer service robots have replaced 40%-50% of human customer service jobs and it is expected that 85% of the customer service tasks will rely on AI by 2020[26] .

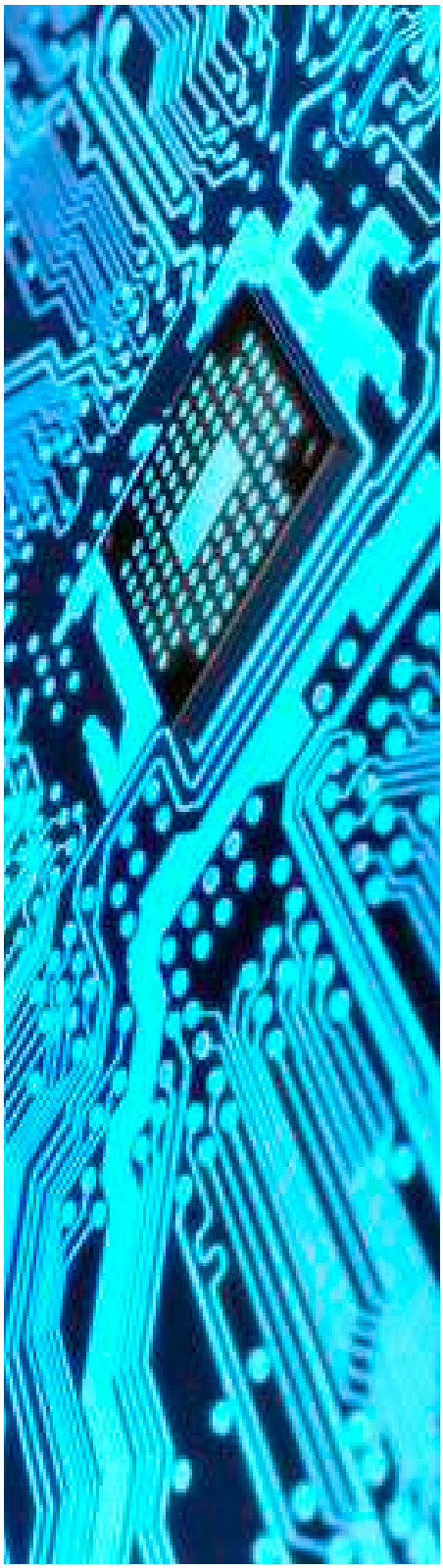
The application of intelligent customer service in the financial industry is mainly seen in the banking, insurance, and internet finance sectors. Traditional financial institutions such as banks and insurance companies tend to acquire local solutions from IT service companies to ensure data security and mitigate potential leakage risk. Due to the diversified needs of traditional financial institutions, customized solutions are offered by IT service companies. In the internet finance sector, intelligent customer service mainly adopts the SaaS model, and it is mainly used by major internet finance companies.

In China Merchants Bank Credit Card Company, for example, intelligent customer service is leveraged to provide more than 2 million times of online human-machine interactions per day for customers, resolving 99% of users' questions. Intelligent customer service not only enhances customer service efficiency with 24-hour uninterrupted service to improve user experience, but also reduces costs significantly. An increasing number of financial companies are starting to adopt intelligent customer service systems and are making them the primary means of customer service. Human customer service representatives have shifted from the main role to the supportive role, and will even be completely replaced in the future with the advance in the AI technology.

### Intelligent investment advisory broadens range of service of the long-tail customers

The application of AI robots in investment advisory liberalizes the ways of wealth management. The once costly and labor-intensive service is becoming a product, and technology is extending financial services to groups beyond the traditional wealthy class. For example, Lufax provides corporate or individual investors with comprehensive financial asset transaction information and advisory related services.

Chinese residents have huge investment assets, expected to reach RMB237 trillion by 2020, which will lay a foundation for the extensive development space of intelligent investment advisory in China.



26. Gartner

Intelligent investment advisory as online tools can automatically analyze the customer's financial profile and leverage big data analysis to provide customized recommendations. It can also manage investment portfolio to invest in quality products. Currently, there are two key types of models:

Trading procedures provided by financial institutions such as banks. Some robot advisors only invest in passive investment portfolios (such as ETFs) and do not allow modification of investment strategies by clients. Other robot advisors allow clients to take active part (such as selecting stocks) and charge service fees for modification of investment portfolios and other services. For example, "Machine Gene Investment" offered by China Merchants Bank provides investment advisory services. In 2016, the average buy amount of accounts reached RMB36,900[27] .

The other type of model is based on social media platforms, which allow users to exchange investment options, strategies and market insights. Individuals may create investment portfolios and share with other investors. One of which is retail algorithmic trading, which enables investors with limited technology knowledge to obtain effective investment algorithms and benefits, and share only part of the profits from the investment returns with the algorithmic authors. For example, Quantopian was founded in Boston in 2011 to "inspire talented people everywhere to write investment algorithms". Indeed, it means that the company leverages the internet community platform to provide scientists, developers and students with resources and basic frameworks and let them cooperate and use financial data, education tools and research data. With the thousands of investment algorithms submitted, Quantopian selects the best solutions based on risk, returns, potential and other factors. From the most basic way of its operation, Quantopian is like a crowdsourcing investment company in which algorithmic authors allow the platform to use the most effective algorithms among their work and to gain profit-sharing from designing investment algorithms.

To financial institutions, these trends indicate that the middle-class market is being eroded. Retail banking will face competition as new market entrants may offer more commoditized wealth management products. In the high-net-worth market, individual wealth planners are playing a more important role. In addition, retail banks may provide automated services to fulfil most of the needs of wealth management customers, but they need to adapt to customers' investment preference. Therefore, wealth managers may need to modify their value proposition to maintain their operation.
In the future, advisory service may be separated from products. Customers will turn to the emerging, cost-effective automated advisors. The number of wealth products sold via their own advisory channels will further reduce. Traditional wealth managers will also see weakened advantage of the economy of scale. More and more processes will become automated and the number of customers using virtual channels will be on the rise. New entrants will continue to use low-cost architectures. It can be foreseen that the revenue of traditional wealth managers will decrease in the future, and competition among traditional industry players in professional areas or service providers will intensify.

**Intelligent risk management mitigates financial risk**

In the current stage, personal consumption expenditures in China is growing rapidly, becoming the key force driving China's economic growth. With the increase in demand for loans, the number of financial frauds is also on the rise. Built by combining AI and big data technology, the intelligent risk management system performs comprehensive evaluation on data from multiple dimensions including users' transaction behavior, credit status and social relationships to generate the final evaluation results.

Financial institutions adopting intelligent risk management can be classified into three types, namely the comprehensive adopter, technology provider, and proprietary developer.

27. *Reimagined* (重构), Deloitte Research

Comprehensive adopters generally refer to internet giants with both development capability and financial businesses, such as Ant Financial which launched Ant Shield and Sesame Credit, and NetEase Financial (网易金融) which launched Beidou (北斗) risk management system. By offering intelligent risk management products, these companies aim to obtain more user data for the provision of service as a whole.

Technology providers refer to technology companies providing risk management solutions to banks, insurance companies and internet finance institutions, such as Tongdun Technology which offers anti-fraud, credit risk management and data verification services.

Proprietary developers refer to financial institutions that develop intelligent risk management products by setting up in-house technology teams to support their own businesses, such as 360 Finance which developed the Tian Ji (天机) big data risk management system. Through intelligent risk management, financial companies may significantly relieve the problems faced by the traditional financial industry such as frauds, credit risk management, and credit default by more effective means. Capital loss rate is a key metric of a financial company's risk management capabilities. With intelligent risk management, Alipay achieved an average capital loss rate of 0.001%, being highly competitive around the globe.

In addition to the above three areas, AI has rapidly changed the key areas of the traditional financial industry in respect of internal operation of financial companies. Amid continuous changes of consumer behaviors and needs, the traditional financial services industry players are facing remodeling of different areas and processes. For instance, with the constant changes of consumer behaviors and preferences, technology–driven precision marketing and feeds enable the provision of customized products and services, enhancing customer stickiness through technology and allowing the inclusion of smaller businesses in the broader ecosystem. In some areas, customer service representatives are gradually replaced by AI robots to provide inquiry services to customers.

### Figure 4-3: How AI changes the whole operation process

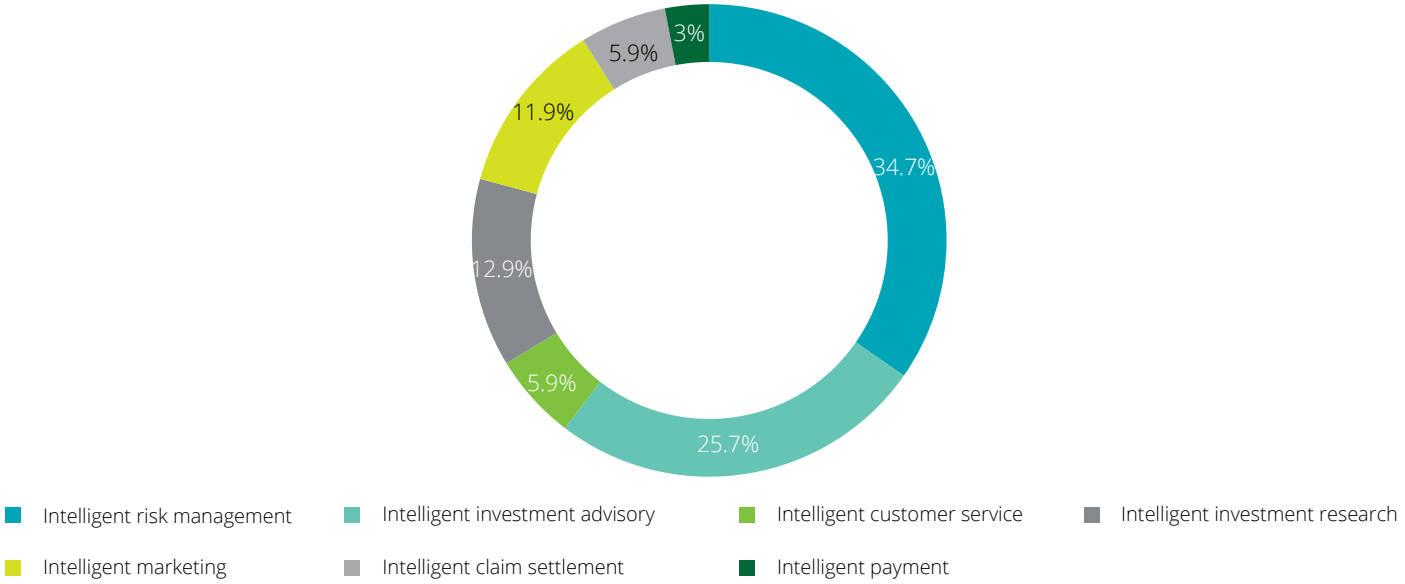
| Business | | Change | Example | Outcome |
|---|---|---|---|---|
| **Front office** | **Service** | • online intelligent customer service<br>• outlet customer service robots | • ICBC's intelligent customer service "GINO" provided over 100 million times of service in 2017 | • reduce labor cost<br>• enhance service efficiency<br>• enhance customer experience |
| | **Marketing** | • precision marketing | • Tencent Financial Cloud performs precise user profiling and labelling by leveraging the marketing big data accumulated in the Tencent ecosystem, and providing marketing feeds using self-developed prioritized advertising algorithms | • enhance advertising conversion rate and reduce marketing cost |
| **Middle office** | **Product** | • customized and personalized products<br>• intelligent investment advisory | • China Merchants Bank's "Machine Gene Investment" has 150,000 users, exceeding RMB 10 billion | • precise product pricing<br>• boost long-tail customers to expand business coverage |
| | **Risk management** | • credit rating<br>• risk pricing<br>• dynamic monitoring | • Ant Financial enabled Alipay to achieve a capital loss rate of lower than 0.001% by leveraging its intelligent risk brain which relied on massive data. It is leading globally. | • reduce risk claims<br>• reduce bad debt risk<br>• identify financial frauds quickly |
| **Back office** | **Management** | • internal risk management<br>• intelligent office | • Ping An Group performs remote intelligent management based on data modeling and visual presentation | • enhance management efficiency and reduce management cost |
| | **Data** | • data analysis<br>• active data security and protection | • Tencent and Beijing Municipal Bureau of Financial Work co-developed a Beijing-based financial security big data supervision platform to identify, monitor and provide early warnings on all types of financial risks in order to prevent and manage financial risks | • enhance data security rating and reduce business risks |

Source: public materials, Deloitte Research

At present, intelligent financial applications based on AI have been implemented on a trial basis in many places. Currently, there are 139 intelligent financial companies in China, of which 44% have obtained round B/post-round B investments.

The specific application areas of these companies mainly include intelligent risk management, intelligent investment advisory, intelligent customer service, intelligent investment research and intelligent marketing. Of which, intelligent risk management and intelligent investment advisory companies accounted for more than half of those companies, being the most popular capital orientation.

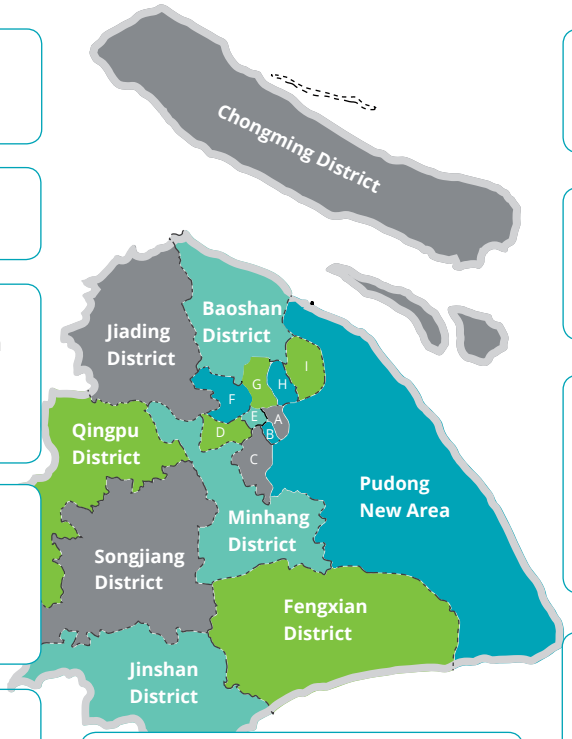
**Figure 4-4: Distribution of different types of intelligent financial and investment companies**




Source: iResearch, itjuzi.com, Deloitte Research

As one of the most developed cities in China's financial industry, Shanghai, the national artificial intelligent center, put forward the idea of integrating AI and finance earlier. In Shanghai, there are 39 representative intelligent financial companies focusing on 14 areas. The majority of the intelligent financial companies are located in Pudong New Area, largely engaging in online lending, InsureTech, consumer finance, intelligent payment, and supply chain finance.

**Figure 4-5: Distribution of key intelligent financial companies in Shanghai**




**Baoshan District**
Chongrong Financial Information Service—stock forecast

**Jiading Distict**
Huilicai—wealth management app

**Minhang District**
Surong 360—social credit information platform
Ziwei Financial—wealth management and investment platform

**Changning District**
Tigerobo—intelligent financial information search engine
Achain—public blockchain platform
eulerfinance—smart investment

**Jinshan District**
Meidan Information—financial services

**Xuhui District**
afajr—Smart ivestment
wuyintong—blockchain financial services
iqunxing—Financial service platform

**Putuo District**
quanerp—enterprise informationzation
buyfunds—AI financial solutions

**Jingan District**
51xtr—payroll services
leapstack—intelligent insurance
Chinascope—financial data

**Yangpu District**
Jingshu Finance—Financial business services
chancein—stock data services
profeto—intelligent finance
xinshucredit—Big data

**Pudong New Area**
fantaiai—Financial technology services
betawm—Data solutions
icekredit—Big data

A Huangpu District B Luwan District C Xuhui District D Changning District E Jing'an District F Putuo District G Zhabei District H Hongkou District I Yangpu District

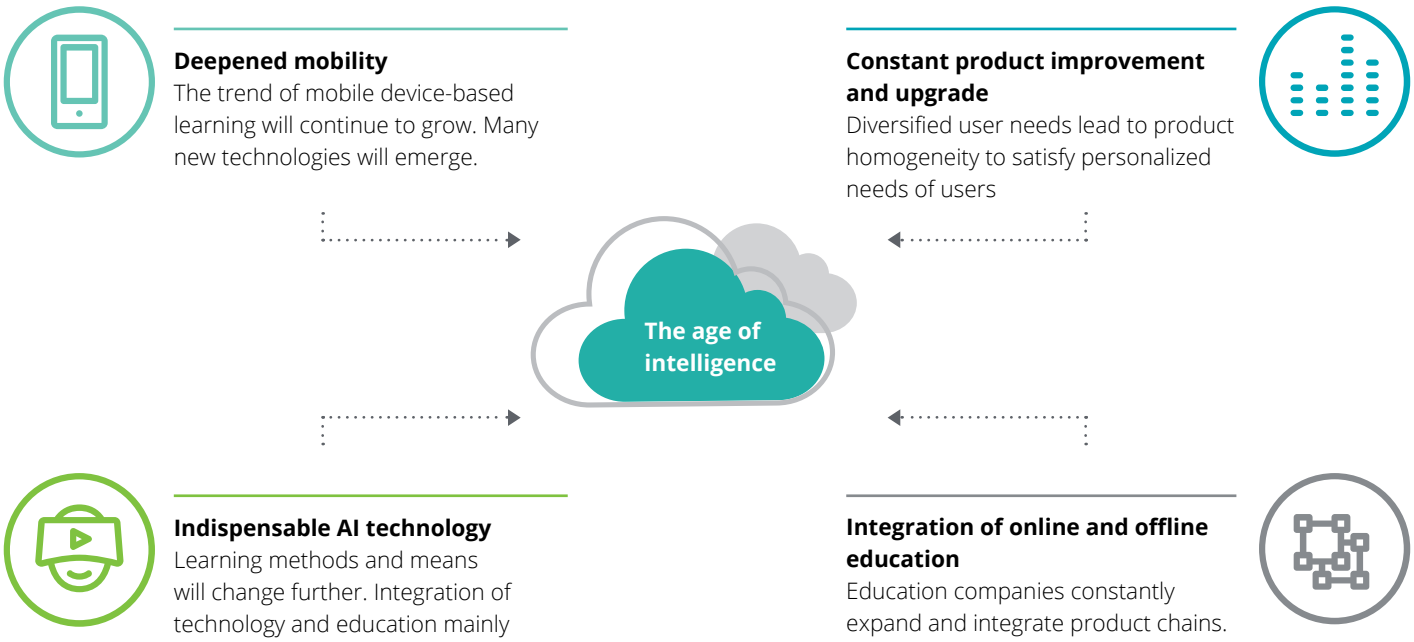
Source: ASKCI Consulting, Deloitte Research

### 4.2 Education: AI application covers the whole education process

New technologies will continue to change the education industry. The emergence of the AI technology has brought about the intelligentization trend in the education industry, as well as trends of mobility, product homogeneity and online-offline integration. These trends will restructure the relationship among players in the education industry ecosystem, improve students' learning efficiency and redefine the education industry.

From the perspective of industry development stages, AI education sector now is still in a development stage and has not reached its maturity. Though a hot concept, AI empowerment in education industry cannot be accomplished at one stroke. Throughout AI's development and application process in education industry, the main focus was on the planning and preliminary exploration of AI education at the beginning. In the 1950s, Allen Newell and Herbert A. Simon, both professors at Carnegie Mellon University and pioneers of AI, promoted the development of AI in combination with mathematics, engineering and economics. In the 1970s, Jaime Carbonell created an intelligent tutoring system and started to teach with assistance from computers. In 1993, the first Artificial Intelligence in Education (AiED) World Conference was held in Edinburg, England. Over time, AI education has also entered into an official stage of development, with intelligent adaptive education enterprises including Cognitive Tutor, Knewton and RealizeIt being established in the US in the early 21st century, and AI technologies are increasingly applied in education industry. Intelligent adaptive learning is an AI educational technology that simulates the one-to-one teaching process between teachers and students, empowering the learning system with individualized teaching capabilities. After 2010, China's intelligent adaptive education enterprises started to emerge, including New Oriental, TAL, Yixue Education, etc. Since around 2016, TAL, New Oriental and many other well-known education institutions as well as capitals have begun investing in AI education.

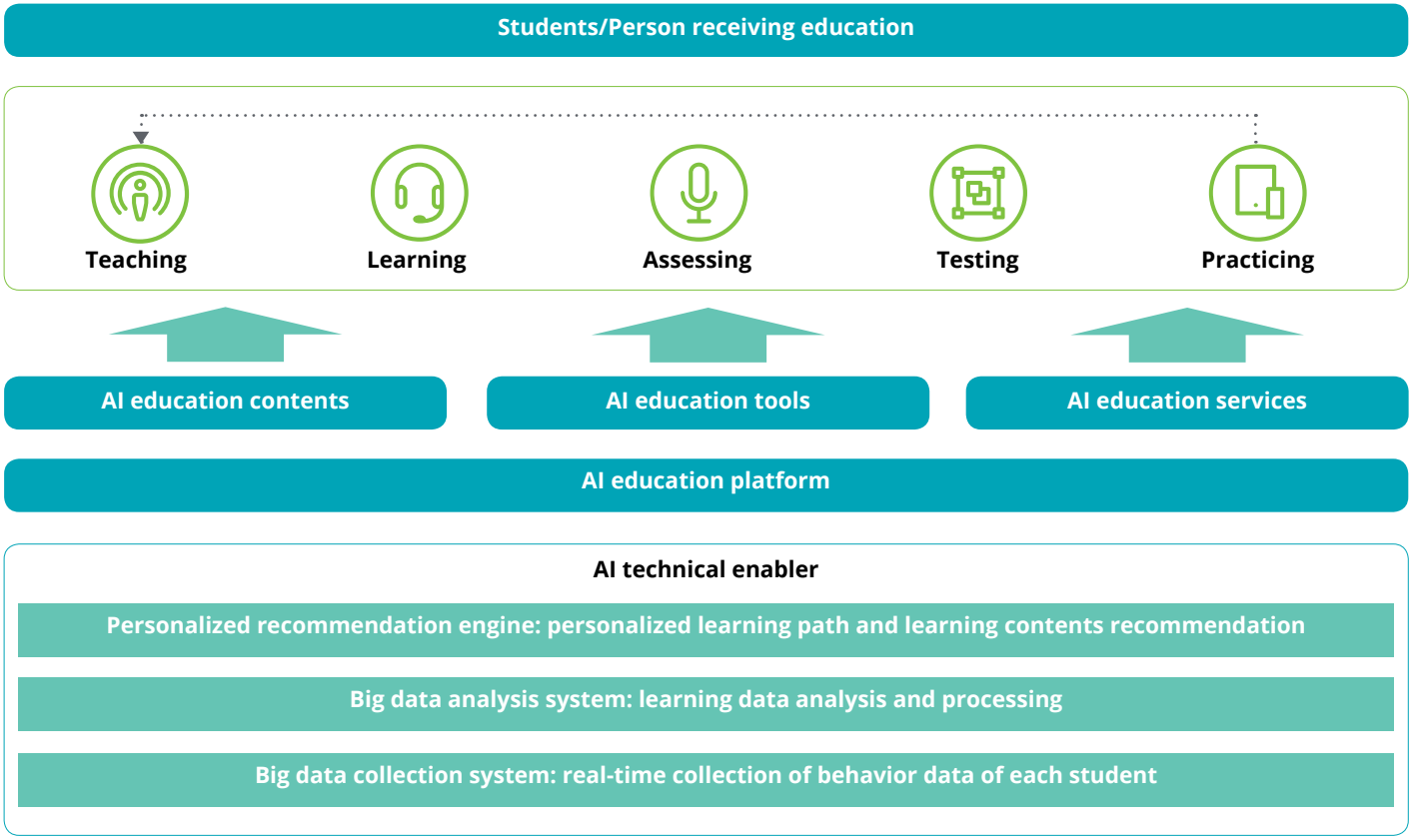
**Figure 4-6: The intelligentization trend in China's education industry**




Source: Deloitte Research

AI will restructure the ecosystem of the education industry. AI is a technology that intelligently processes massive data based on big data capturing and multi-dimensional recognition systems, and achieves information interaction with humans through interactive interface and application scenarios. Based on the AI technology, education companies provide users with AI-based education content, tools and relevant services. They collect, analyze and give feedback on user data, then apply them in five processes: teaching, learning, assessing, testing and practicing, and finally develop customized solutions and effective feedback.

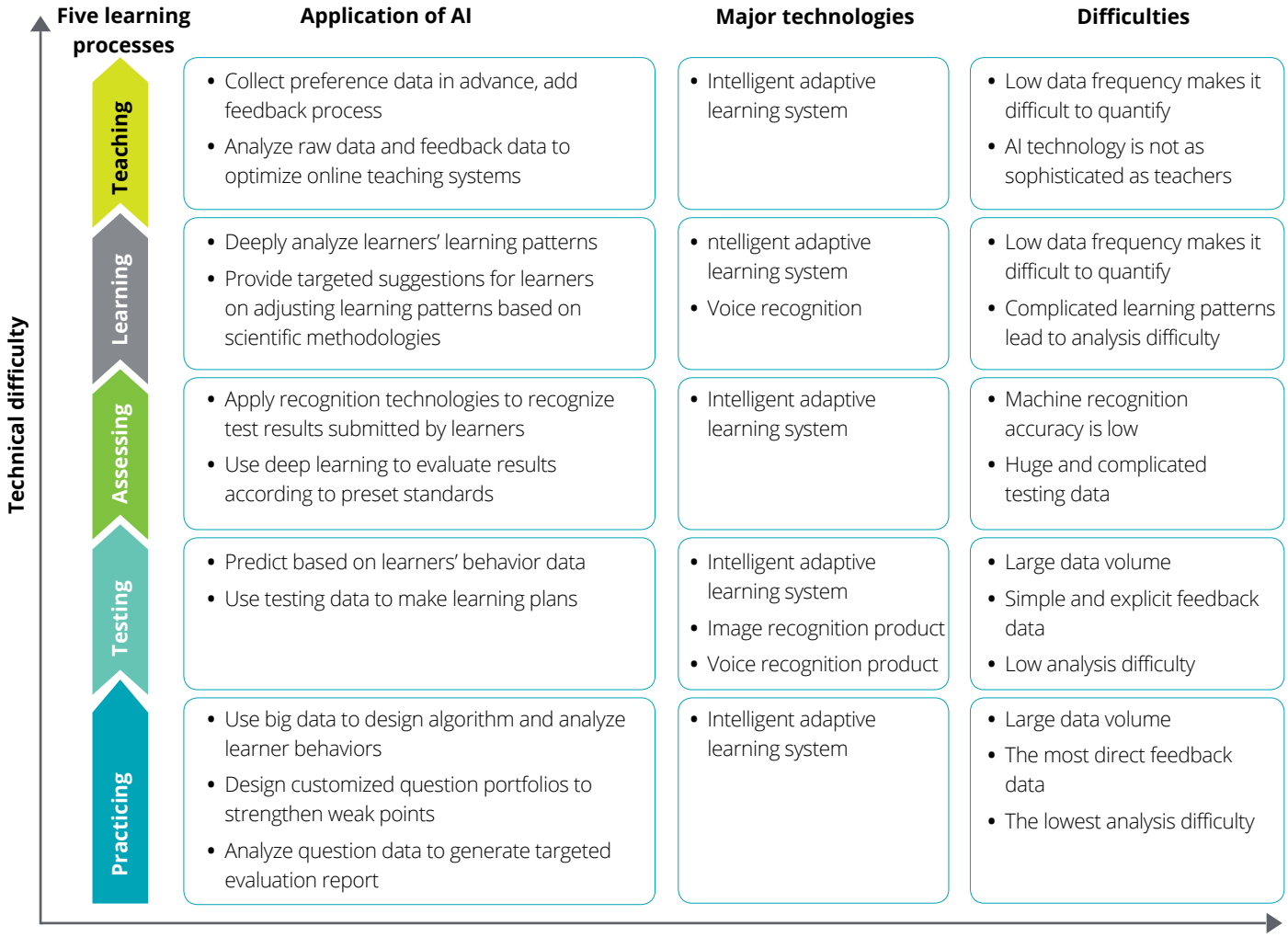
**Figure 4-7: Illustration of the AI-based education structure in China**




Source: Deloitte Research

Under the intelligentization trend, intelligent adaptive learning has become the most widely applied AI technology, given its unique advantage of being able to penetrate the whole learning process. It will gradually become the mainstream. Besides, image recognition products and voice recognition products are also applications of AI in education.

**Figure 4-8: The application of AI in the five learning processes**




Source: Deloitte Research

Mainstream products in current AI education sector include intelligent adaptive learning system, intelligent assessment, intelligent dual-teacher classroom, and intelligent accompanying robots, etc. Top enterprises of intelligent adaptive learning system in China include Yixue Education—Squirrel AI; intelligent assessment enterprises are represented by iFLYTEK, Singsound, Liulishuo, Pigai, etc.; intelligent dual-teacher classroom is led by TAL's Intelligent Classroom and Yixue Education—Squirrel AI's AI + human dual-teacher classroom.

**Intelligent adaptive learning systems**

Intelligent adaptive learning systems can provide real-time and customized learning solutions based on students' learning status, including knowledge reserve diagnosis, competence assessment and content recommendation. For example, in the teaching and learning processes, learners vary with each other in learning status and competence. Leveraging the AI technology, intelligent adaptive course systems can use big data and algorithms to develop a set of effective and standardized courses according to important and difficult teaching points such as knowledge point extraction and learning method induction, offering the most suitable courses for learners of different levels. Computing power improvement, massive data and the application of Bayesian network algorithm have greatly accelerated the development of adaptive learning systems since 2010 and significant results have been achieved. Knewton's adaptive learning assisted Math courses have significantly improved the pass rate of students at Arizona University and reduced course withdrawal rate by 56%. Intelligent adaptive learning technologies and products develop differently in China and overseas. In the United States and Europe, intelligent adaptive companies are more developed, serving mainly To B users, and are represented by Knewton, ALEKS, RealizeIt and DreamBox. Chinese intelligent adaptive companies are still in the initial stage and mainly serve To C users. However, adaptive learning is developing at a faster pace in China and is expected to surpass the foreign countries.

**Figure 4-9: Effectiveness of adaptive learning systems**


Source: Knewton, Arizona University, Deloitte Research
Note: the effectiveness of learning with Knewton's adaptive learning assisted Math course introduced by Arizona University

The integration of the AI technology and learning information management system is an integral part of intelligent adaptive education products. By applying cloud computing and the deep learning function of AI, they can customize homework, testing and courses and conduct scientific assessment. AI technology has been introduced into schools and some education companies to track learning status, record learning data, evaluate proficiency, manage learning progress and connect parents with schools. By using open big data, it can challenge traditional teaching systems, make teaching more targeted, quantify and visualize learning progress, and improve teaching and learning quality. Currently, inadequate user coverage limits the application of learning information management system in K12 sector.

Besides, data openness is very important. With open big data, education tech companies can use the AI technology to conduct analysis and give feedback, which could help companies and schools improve teaching plans and education quality. Moreover, companies can provide technical support for offline education entities with their technical strength and data reserve. Now, education companies and IT companies mainly provide open data in vocational and K12 education sectors.

At present, intelligent adaptive learning products mainly play the assistive role in teaching, while it is unable to completely replace teachers. In the teaching and learning processes, learners vary with each other in learning status and competence. Leveraging the AI technology, intelligent adaptive course systems can use big data and algorithms to develop a set of effective and standardized courses according to important and difficult teaching points such as knowledge point extraction and learning method induction, offering the most suitable courses for learners of different levels.

**Intelligent assessment products**

A major branch of AI education, intelligent assessment is divided into voice and essay assessment based on different types of learning. Voice assessment is represented by iFLYTEK, Singsound and Liulishuo, while essay assessment are represented by iFLYTEK and Pigai. Speech recognition is an AI technology that has been put into commercial application in the early stage. Currently, education companies mainly apply it to conduct speech assessment for oral language learners. Speech recognition technology assess user's oral language automatically from multiple dimensions including pronunciation, semantic meaning and expression. More importantly, the application scenarios of speech assessment technology has been extended from shadow reading to open questions. For oral language learning, speech assessment products have two user groups: first, ToB education institutions. They mainly use speech assessment products in language testing such as CET 4/6 oral testing, mandarin testing etc.; the other one is ToC users. Since the time for class exercise is limited, speech assessment products have been embedded into many learning systems to help students practice oral language after class.

As speech assessment products are dependent on data, education companies with leading advantage in speech assessment will be stronger. The accuracy of speech assessment products is not only closely related to algorithm, but also has close ties with the validity and diversity of corpus in the database. With enough training data, algorithms would be able to extract features more accurately and reasonably in the process of assessment. If all training data is provided by male users, then male users will get higher scores than female users. Moreover, enough training data also can help extend speech assessment to other languages. Companies with large user base can obtain more diversified data, develop better products, attract more users, and achieve sustainable development, therefore, they could have bigger chance to succeed.
The lack of ToB education companies creates huge demand for speech assessment products. China has even more urgent demand for speech assessment products due to the lack of excellent foreign language teachers and uneven oral language teaching quality in second and third tier cities. On the other hand, in Chinese schools, one teacher always has to teach more than 30 students. With limited practice and guidance, students can't learn oral language well as listening, speaking and writing. ToB market has huge demands, but companies focusing on this segment (including extracurricular education institutions, education training centers and schools) are far from enough.

### 4.3 Digital government services: favourable policies expedite intelligent transformation

Similar to other sectors, governments are expediting intelligent transformation after witnessing significant achievements of AI in cost reduction and efficiency improvement. With the great support of urbanization strategies, China has achieved the highest urbanization growth rate in the world. In 2018, the urbanization rate of reached 60%, with around 730 million of urban population. By 2050, China will have larger urban population and make urbanization rate exceed 80%. Large urban population will generate massive government affairs. Governments can use robotic process automation (RPA) and AI to relieve administrative officials from repetitive tasks, enhance service efficiency, strengthen city development quality, and improve urban living environment. Under the background of AI empowerment, technologies like face recognition and natural language processing will help enhance government service quality, improve working efficiency, bring convenience for enterprises and citizens, and realize intelligent decision making.

Building digital government with top-down efforts. To build service-oriented governments, an e-government trend gained popular nationwide since 2015. As new technologies such as AI, big data, and cloud computing are putting into commercial application, this trend transforms into digitalization and intellectualization. The value of China's digital government market is expected to exceed RMB340 billion by 2019, with 15% of CAGR.

**Government services: core elements of digital government construction**

Government service is one of the most important and the fastest growing area in digital government construction. Local governments are energetically building one-stop service platforms in order to provide intelligent government services. For example, Shenzhen Municipal Public Security Bureau migrates offline service windows to its online portal. Citizens can deal with household-related affairs after "facial scanning". It also develops an integrated government information and resource sharing system for Shenzhen with 3.8 billion items of data (385 categories of information and resources) from 29 government departments[28] and public institutions to provide data support for comprehensive intelligent government construction. Moreover, Hangzhou develops an integrated smart e-government management system to migrate urban management system, urban planning system, and financial service system on a one-stop service platform.

Since government departments are somewhat disconnected and have different intelligent service demands, intelligent service systems provided by companies are always designed to improve certain government services. For example, to facilitate tax inspection of local tax authorities, Ultrapower provides Chinese text analysis, transforms text as structured data, and searches related data via Internet to dig the relationships between companies and shareholders.

Backed by AI technologies, government services will be friendlier and more targeted. On one hand, citizens and companies can have easier access to public services, rather than simply through online portals; on the other hand, AI-based decision making will be more effective and accurate and flexible.

28. "To learn the benefits of government information resource sharing from Shenzhen's experience" (《从深圳政务信息资源共享实践成效充分认识政务信息资源共享的基础性作用》), Xinhuanet.com

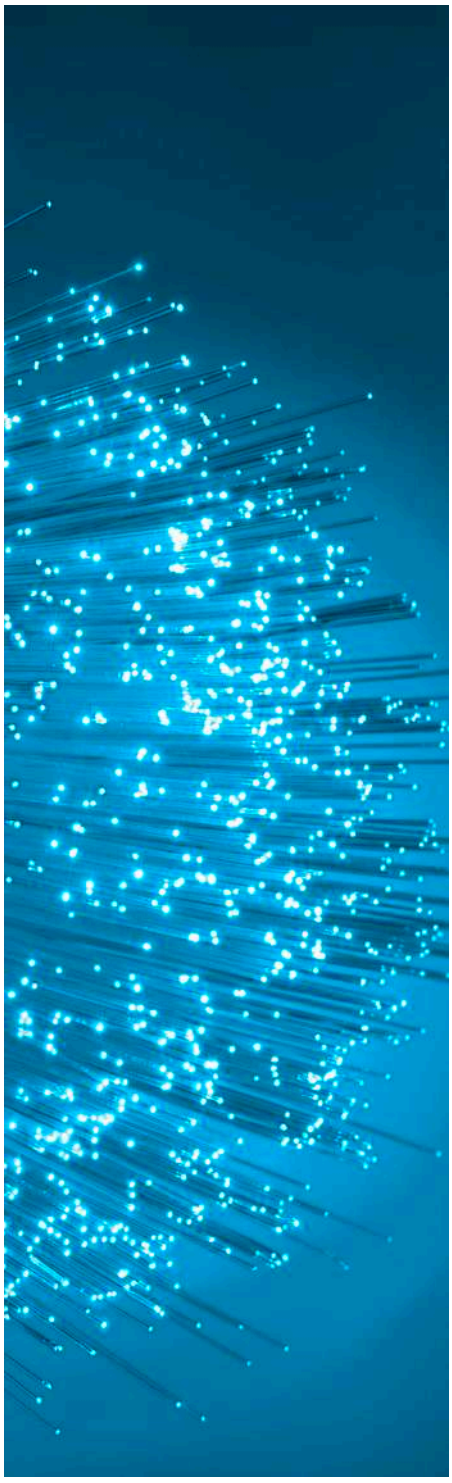
### Leading public security service providers will get stronger

AI is playing an increasingly important role in urban security. Compared with the existing digital security, AI-based security system can provide real-time and intelligent public security management. In China, smart city construction is gaining momentum. As an important part of smart city construction, public security will have broader development space, as local governments are paying increasing attention to it. By 2020, the revenue of security sector is expected to reach RMB800 billion with higher than 10% annual growth[29] . There are two types of AI-based security companies: product or service suppliers and security system solution providers.

Product suppliers mainly refer to companies that provide certain products or services for the whole security system. For example, Cloudwalk assists Guangdong Provincial Public Security Department to deploy face recognition system in key places such as subways and bus stations. When searching for suspects, it compares the appearance features of suspects with real-time surveillance video. The face recognition system can help find, track and catch suspects, reduce manpower in post investigation, analysis and decision making, and greatly improve working efficiency. PERCENT helps the police to integrate internal and external data, use big data and cognitive intelligence technology to combine and analyze multi-modal data, carry out data-based digital surveillance, develop smart police services, accurately identify criminal behaviors that are under planning and potential risks, and shift the focus from post-investigation to proactive prediction, warning and precaution.

Security system solution providers are companies that provide all security system products and services, covering pre-consultation, planning, product provision, operation and maintenance and aftersales services. These companies are powerful, represented by Hikvision, Dahua Technology and Huawei. Hikvision and Dahua Technology are integrated solution providers transformed from intelligent hardware suppliers, they are expanding markets with rich security technology experience. Huawei is a representative of platform providers. It builds security ecosystem with cloud technology and experience. In 2017, Huawei established China Safe City Video Cloud Partner Open Alliance with companies including Sense Time, YITUTECH etc. In 2018, the alliance developed solutions to apply safe city public security videos in multiple areas.

AI-based security market is still growing, leading players are getting stronger. The competence of companies depends on technical ability and system solution. As the requirements for market access increase, technologically backward companies will be knocked out and industry concentration will be further improved. AI-based chips are increasingly important for intelligent



29. 13th (2016-2020) Five Year Development Plan for Chinese Security Industry (《中国安防行业“十三五”(2016-2020 年) 发展规划》), China Association of Work Safety

security services. By 2020, the number of sensing devices in IoT will reach 50 billion[30]. If companies send massive data collected by them to the cloud, the broadband will be under huge pressure. Edge computing will bring great benefits for the security sector including reducing the time from data to decision making and cutting transmission and storage costs. Therefore, security service providers will gradually expand from downstream to upstream and enhance the application of intelligent technologies.

### 4.4 Healthcare: AI-based applications are getting mature

In face of numerous social problems, such as aging population, growing chronic disease patients, quality medical resource shortage and higher public medical costs, AI-based medical services will bring the healthcare industry with new hope and momentum. With the application of more AI technologies in healthcare industry, tedious medical treatment procedures will be simplified, medical resource allocation will be optimized and medical technologies be improved.

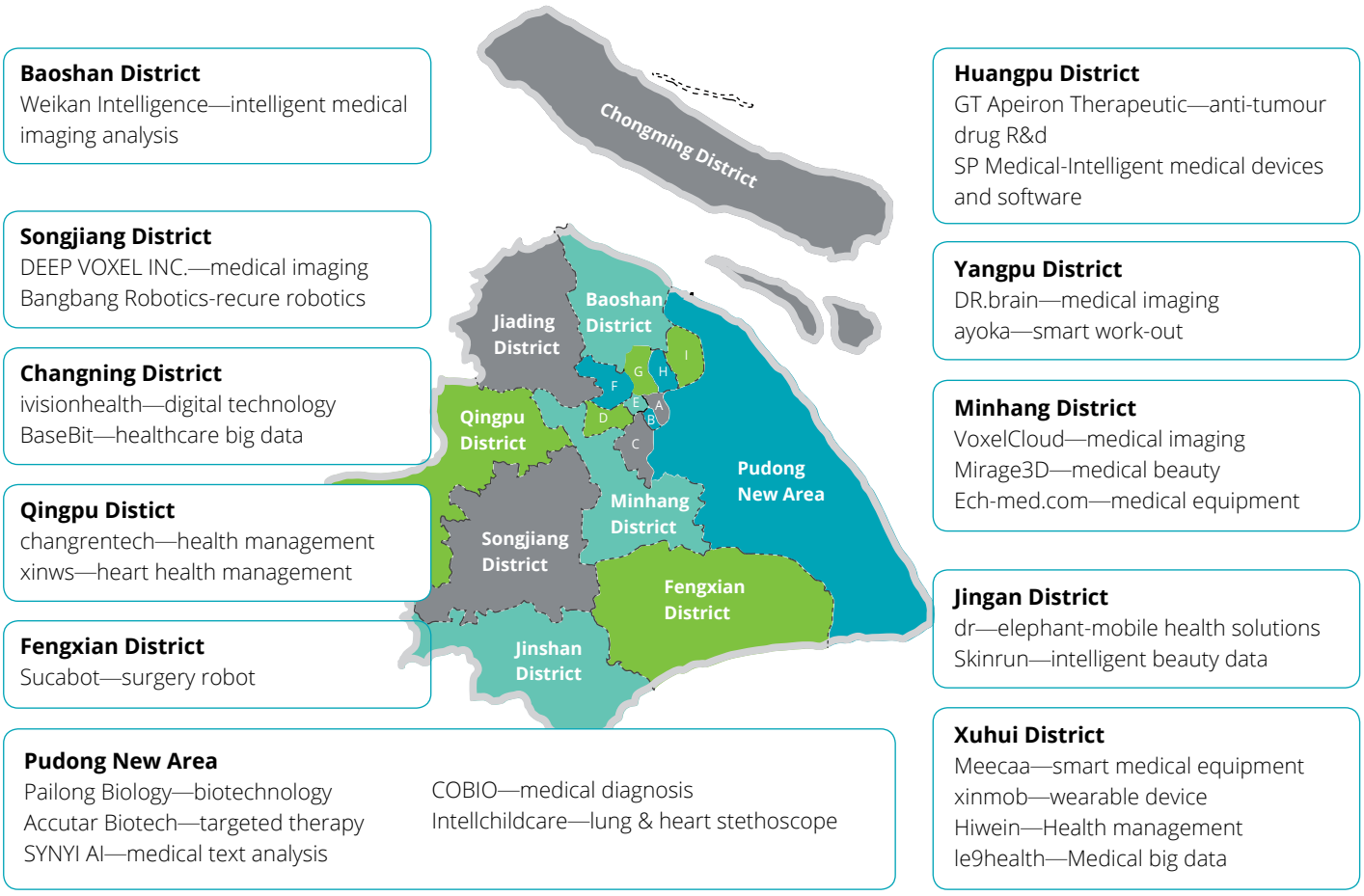
According to the *Development Planning for a New Generation of Artificial Intelligence* released by the Stata Council, China clarifies the goal of increasing the size of major AI-based industries to over RMB150 billion by 2020. As estimated, AI-based medical industry will account for one fifth of the total AI market. In 2016, the value of China's AI-based medical industry was RMB9.661 billion, with 37.9% of growth. In 2017, this number exceeded RMB13 billion, increasing by 40.7%. And it is expected to hit RMB31 billion by 2019.

In terms of market demand, due to the shortage and uneven allocation of medical resources, the market is in urgent need of more open and efficient medical solutions. In terms of technology development, with significant progress in computing vision, natural language understanding and data mining, the implement of AI-based medical applications gain more technology support. As for policies, developing healthcare industry based on Internet and AI technologies is always the focus of our national policymakers. In April 2018, the State Council clearly showed its support for healthcare-related AI technologies through the Opinions on promoting the development of "Internet + healthcare". These policies are positive signals for the development of AI-based healthcare industry.Chinese AI-based medical companies are late comers but maintain fast growth. In recent years, such start-ups constantly increase and get huge capital injection. China has 144 smart medical companies, most of them are based in Beijing, Guangzhou as well as the Yangtze River Delta. They are focusing on disease screening and prediction, medical imaging diagnosis, medical records and documental information analysis, as well as new drug research. In 2018, companies engaged in disease screening and prediction got the most financing. Except large state-owned enterprises, tech giants such as Baidu, Alibaba, Tencent and iFlytek also actively invest in these start-ups.

In the past several years, Shanghai has become a fertile land for "AI + healthcare" for its inherent advantages. First, platform advantage. With large medical service demands and outstanding scientific research capability, Shanghai accumulates systematic and complete medical data, which lays a solid foundation for providing AI-based medical services. Second, international market access and favourable entrepreneurship environment. Shanghai gathers mainstream medical information companies and Internet companies, attracts abundant capital and talents, and has formed advantages in medical imaging, minimally invasive surgery and drug research. Third, Shanghai makes a good start in promoting industry-university-research-application integration and cultivates many excellent electronic and intelligent medical equipment companies, which will benefit AI research, platform building and data sharing.

30. IDC

**Figure 4-10: distribution of Shanghai's key AI-based medical companies**




**Baoshan District**
Weikan Intelligence—intelligent medical imaging analysis

**Songjiang District**
DEEP VOXEL INC.—medical imaging
Bangbang Robotics-recure robotics

**Changning District**
ivisionhealth—digital technology
BaseBit—healthcare big data

**Qingpu Distict**
changrentech—health management
xinws—heart health management

**Fengxian District**
Sucabot—surgery robot

**Pudong New Area**
Pailong Biology—biotechnology
Accutar Biotech—targeted therapy
SYNYI AI—medical text analysis
COBIO—medical diagnosis
Intellchildcare—lung & heart stethoscope

**Huangpu District**
GT Apeiron Therapeutic—anti-tumour drug R&d
SP Medical-Intelligent medical devices and software

**Yangpu District**
DR.brain—medical imaging
ayoka—smart work-out

**Minhang District**
VoxelCloud—medical imaging
Mirage3D—medical beauty
Ech-med.com—medical equipment

**Jingan District**
dr—elephant-mobile health solutions
Skinrun—intelligent beauty data

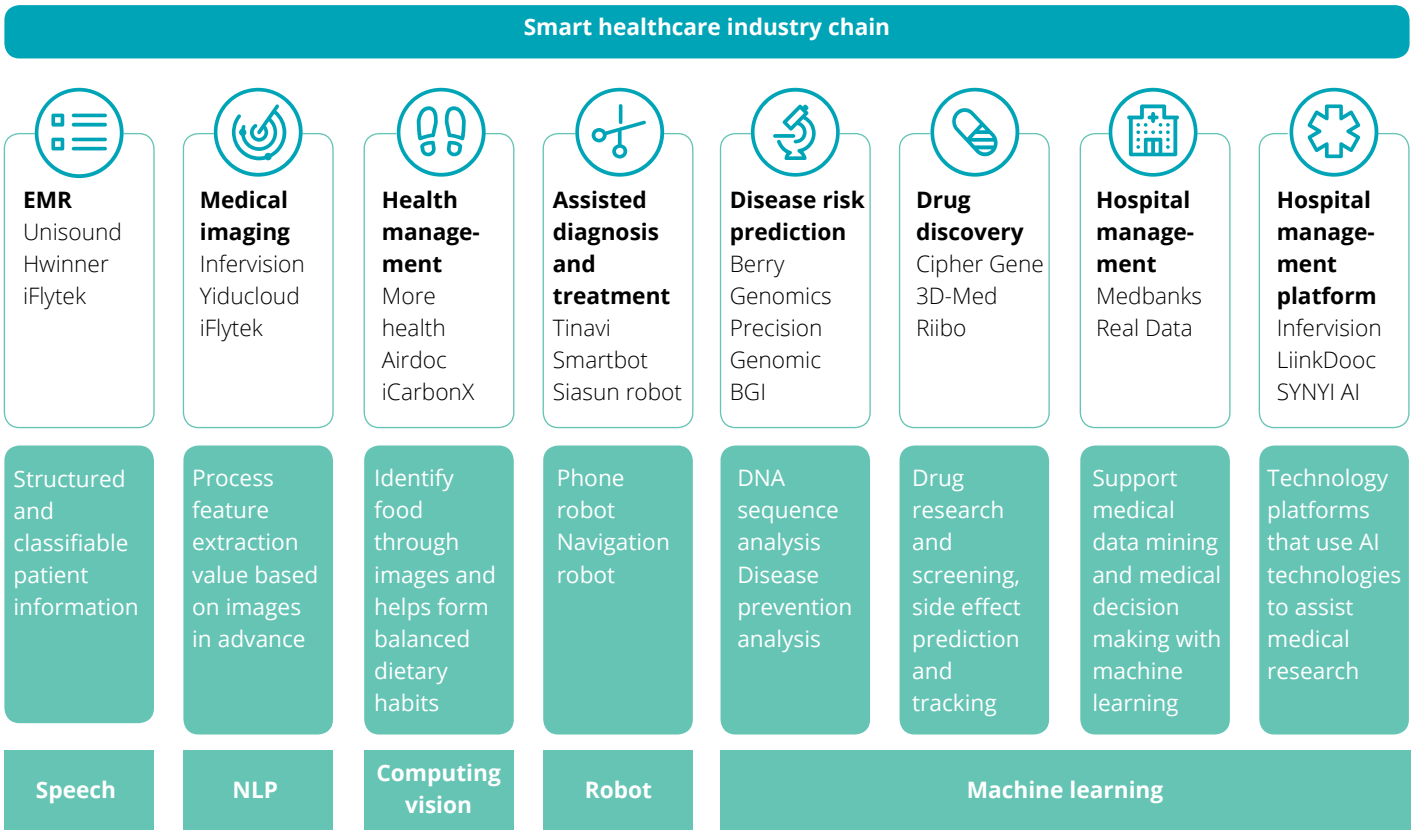
**Xuhui District**
Meecaa—smart medical equipment
xinmob—wearable device
Hiwein—Health management
le9health—Medical big data

A Huangpu District B Luwan District C Xuhui District D Changning District E Jing'an District F Putuo District G Zhabei District H Hongkou District I Yangpu District

Source: IT juzi, Deloitte Research

With the rapid development of AI technologies in healthcare industry, traditional medical concepts, technologies, talents and regulation are facing with challenges. Since traditional diagnosis approaches are deep-rooted, the acceptance level of doctors and patients on new technologies is crucial for intelligent medical service providers. Intelligent healthcare requires massive data and complex training framework, however, not too many companies can meet the above two requirements. Many of them have not developed algorithms to make joint diagnosis on complicated diseases. Besides, the healthcare industry also face the problem of technology and product homogenization. Talent shortage is another restraining factor for AI-based healthcare industry. In China, talents proficient in both medicine and technology are in severe shortage. As for regulation, the healthcare industry is closely related with life safety, patient information should be confidential and safe and be protected by relevant laws and regulations.

**Figure 4-11: smart healthcare industry chain**




Source: Deloitte Research

So far, AI-based medical technologies have basically covered four areas: medical treatment, pharmaceuticals, medical insurance and hospitals. The first batch of AI-based medical products have been applied in three scenarios: intelligent diagnosis and treatment, hospital management and health management.

**Intelligent health management.** It means applying AI technologies in specific health management scenarios such as using medical sensors to monitor health conditions. Currently, such applications mainly include risk identification, virtual nurse, mental health, online diagnosis, health intervention and precision medicine-based health management. With the development of AI technologies, big data has been widely applied in personal medical record, POCT equipment, intelligent health devices and mobile phone apps. Health management aims to prevent diseases and maintain health through individualized management, which is going to be the mainstream of preventive medicine. For instance, Cognitive Care (Hangzhou) develops virtual doctor with medical information, clinical medicine knowledge and virtual technologies to provide follow-up services for discharged patients.

**Intelligent medical imaging.** It refers to applying AI technologies in the diagnosis of medical imaging. AI can be applied in two phases of medical imaging: first, image identification. In the sensing phase, AI can be used to analyze images and get meaningful information. Second, deep learning. In the learning and analysis phase, AI can use massive imaging and diagnosis data to form a deep understanding of neural network and then develop diagnosis capability.

iFlytek and Tencent have entered into the intelligent medical imaging sector. For example, Tencent rolls out a new product Miying, which applies imaging identification, deep learning and other leading AI technologies to help doctors identify early esophagus cancer. With up to 90% of accuracy, it can help patients identify lesion as soon as possible. Moreover, Jianpei Tech, Yiducloud, Zying, RayPlus, Deepinformatics and other Chinese companies also apply AI in medical imaging to improve medical services.

**Intelligent diagnosis and treatment.** It means applying AI technologies to assist diagnosis and treatment. Computers "learn" from medical experts and doctors, imitate the thinking and inference of doctors and then develop reliable diagnosis and treatment solutions. Intelligent diagnosis and treatment is the most important application of AI technologies in healthcare industry.

So far, several intelligent diagnosis programs have been implemented in China, IBM's Watson intelligent diagnosis platform is the most typical one. Watson for Oncology is a cognitive computing system developed by IBM to assist tumour treatment. It has been embedded into Yihui multi-discipline diagnosis cloud platform to support collaborative diagnosis and treatment. Watson cognitive calculation technology provides sufficient clinical evidence for the discussion between doctors, besides, it also help transmit patient data, build knowledge base and offer follow-up services, forming a closed management loop.

As China's leading AI + healthcare application, Tencent Miying is important for Tencent to build the new generation of AI-based medical imaging opening and innovation platform. Now, Tencent Miying can screen for many diseases, including early esophagus cancer, lung cancer, diabetes, retinopathy, breast cancer, colorectal cancer and cervical cancer. The newly published AI-based colorectal cancer screening system can identify adenoma, non-adenoma and adenocarcinoma, provide real-time video enteroscopy examination for the first time, and identify adenocarcinoma with 97.20%  of accuracy. The AI-based diagnosis platform can help doctors diagnose and predict over 700 kinds of diseases, covering 90% of highly-frequent diseases in outpatient departments. The system accumulates about 500,000 medical terms, over 1 million term relation rules, more than 10 million pieces of health tips, and around 80 million items of high-quality medical knowledge.

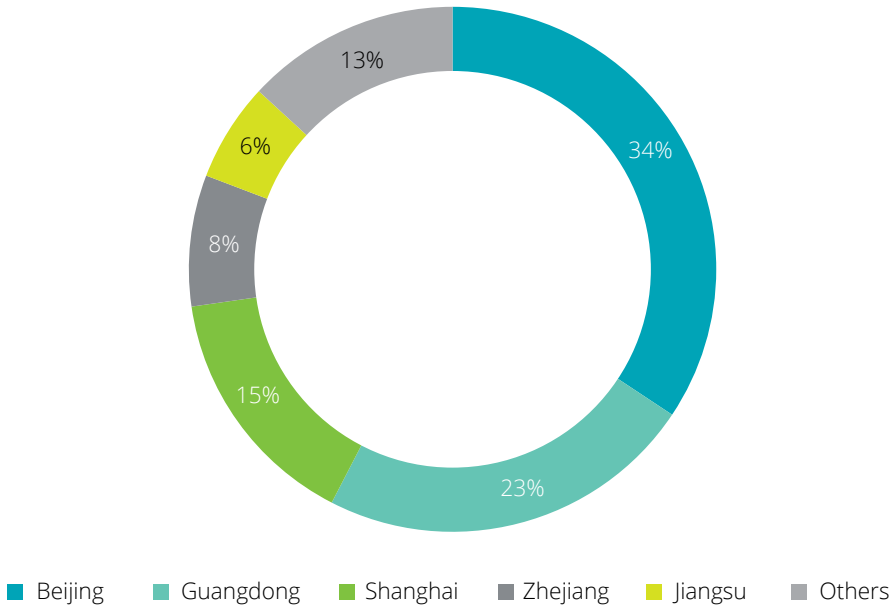
### 4.5 Autonomous driving: leading force in auto industry reforms

In the era of artificial intelligence, auto related smart mobility ecosystem is being redefining. Three major elements of mobility (people, car and road) have their own decisions and behaviors just like human beings. The whole mobility ecosystem will experience dramatic changes. Strong calculation capability and massive valuable data are the nucleus of multi-dimensional collaborative mobility ecosystem. As the application of AI technologies in transportation sector becomes intelligent, electrified and sharable, an intelligent transportation industry chain centered on autonomous diving will be gradually formed.

Autonomous diving is still at the testing phase, but it will have huge market potential in the future. Due to technology and regulatory limitations, autonomous diving cars have not been widely used. Many traditional carmakers and Internet companies such as SAIC, NIO, DiDi, Baidu, BAIC and BMW have completed the first phase of testing (closed road testing), but only several pass the second phase of testing (open road testing), therefore, the autonomous driving market won't have too much changes in the short term. China is expected to roll out autonomous driving cars by 2020. At that time, the sales of autonomous driving cars will reach 60,000 units, and this figure will reach 4 million units by 2035.

As autonomous driving needs strong industrial infrastructure and technology support, China's autonomous driving car companies mainly gather in Beijing, Guangdong, Jiangsu, Zhejiang and Shanghai. Industry cluster effect will get more prominent with the development of autonomous driving and the Yangtze River Delta and the Pearl River Delta will remain the growth poles. Moreover, local policies also have important impact on the distribution of autonomous driving car companies. China's first batch of autonomous driving pilot cities, Beijing, Shanghai, Fuzhou, Chongqing, Changsha, Changchun, Hangzhou, Guangzhou and Shenzhen, have built roads for autonomous driving car testing.

**Figure 4-12: geographic distribution of Chinese autonomous driving companies**



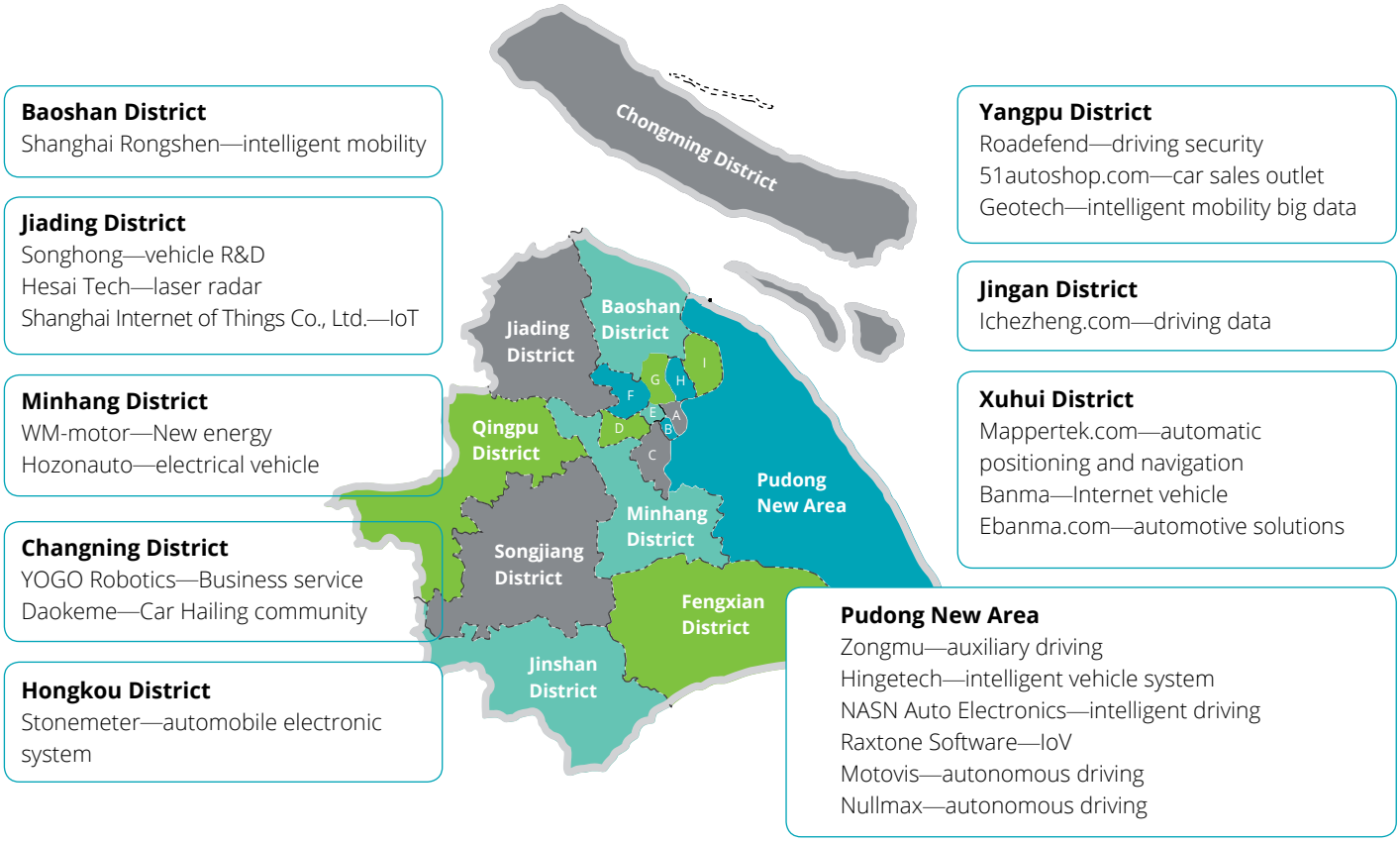

Source: Deloitte Research

From a geographical view, Shanghai is leading the reform in the auto industry. In March 2018, Shanghai officially granted China's first batch of license plates to auto makers for open road testing. Shanghai will allow the testing of intelligent and connected cars as well as autonomous driving cars on roads.

Jiading District, Shanghai has chosen a section of low-risk road (5.6km-long) to test intelligent and connected cars publically. Traditional automaker SAIC and autonomous driving start-up NIO have gained the first batch of license plates. BMW is the first foreign auto brand gaining permission in Shanghai.

Many domestic autonomous driving start-ups such as NIO, Weltmeister, Singulato and Youxia have built R&D centers in Shanghai. Meanwhile, international auto brands including Tesla and Google's Waymo also set up plants and R&D bases in Shanghai.

**Figure 4-13: distribution of major Shanghai-based autonomous driving car companies**




A Huangpu District B Luwan District C Xuhui District D Changning District E Jing'an District F Putuo District G Zhabei District H Hongkou District I Yangpu District

Source: ITJUZI.com, Deloitte Research

From the perspective of user demand, car has been considered as an important transportation tool, however, as car ownership increases, negative impact such as traffic accidents, traffic jams and pollution has gradually emerged. We need new technologies and approaches to make transportation safer, more comfortable, economic and environment-friendly. Traditional auto makers are making technology breakthroughs. Mainstream car makers, no matter technology companies or manufacturers, have reached a consensus on cross-border cooperation: data and connection will be the key words in the era of smart mobility. Some technology companies have initiated cross-border cooperation with relevant departments and auto manufacturers, to achieve reasonable resource sharing and allocation. To build multi-dimensional collaborative mobility ecosystem in the era of smart mobility, strong computing power and massive valuable data are necessary.

**Figure 4-14: grading of autonomous driving technologies**

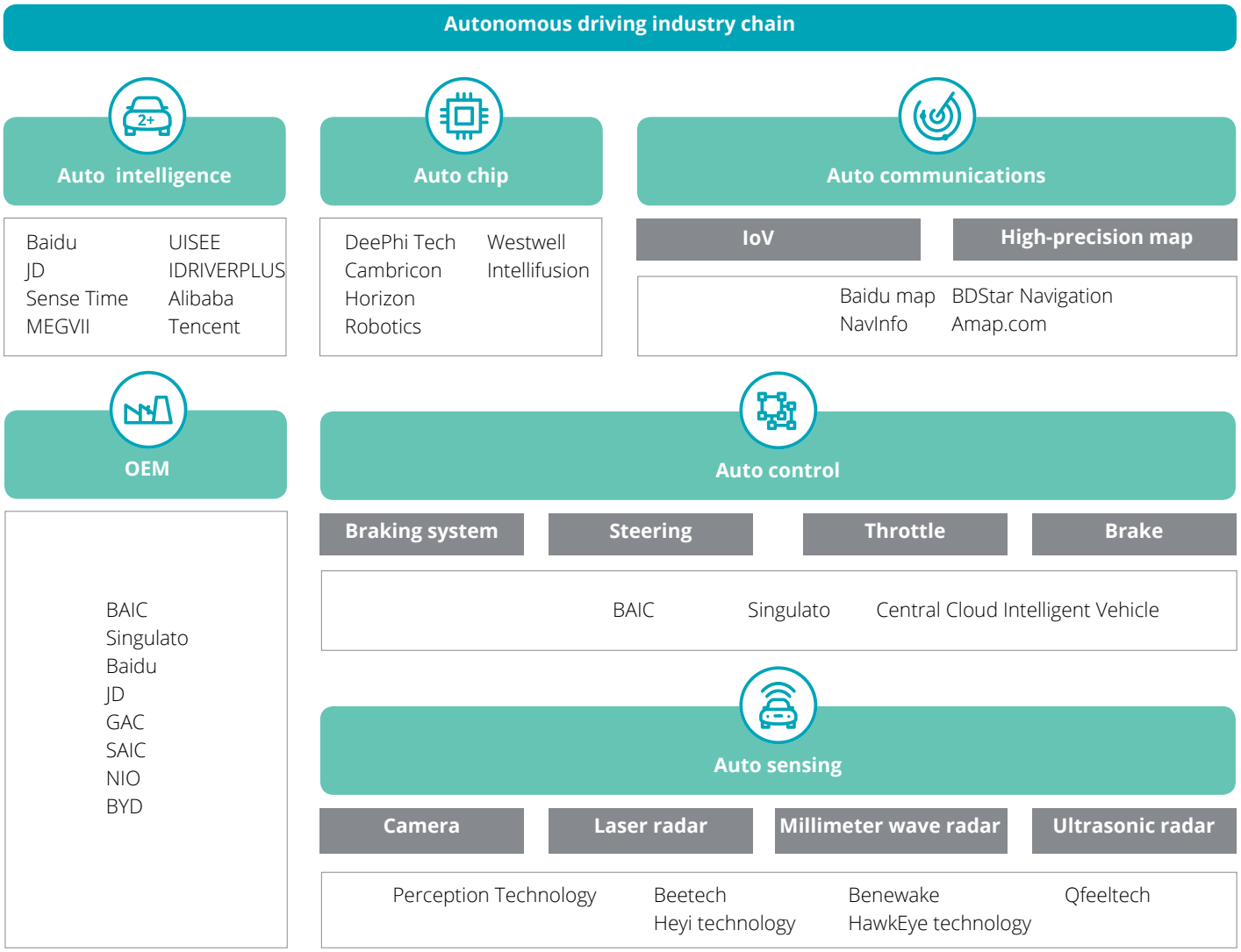
| rading of autonomous driving technologies | | Name | Definition | Driving operations |
|---|---|---|---|---|
| **NHTSA** | **SAE** | | | |
| **L0** | **L0** | Manual driving | People drive cars safely | Driver |
| **L1** | **L1** | Auxiliary driving | Vehicles complete only one operation related with steering wheel and speed, drivers are responsible for other driving operations | Driver and vehicle |
| **L2** | **L2** | Partly autonomous driving | Vehicles complete several operations related with steering wheel and speed, drivers are responsible for other driving operations | Vehicle |
| **L3** | **L3** | Conditional autonomous driving | Vehicles complete most driving operations, drivers need to stay focused and be prepared for unexpected situations | Vehicle |
| **L4** | **L4** | Highly autonomous driving | Vehicles complete all driving operations, drivers don't need to stay focused in certain roads and environment | Vehicle |
| | **L5** | Fully autonomous driving | Vehicles complete all driving operations, drivers don't need to stay focused | Vehicle |

Source: SAE, NHTSA, Deloitte Research

Vehicles began to have intelligent functions since 2000. GPS and sensors provide data and application support for autonomous driving. Since the rolling out of GPS, many tech and auto companies have begun to accumulate personal mobility data. AI use massive data to learn driving skills. Sensor enables vehicles to sense and judge the surroundings. For example, ABS, safety bag and ESC make vehicle more comfortable and safer. The real intelligent auto trend starts from the second decade of the 21st century. Following Google's efforts in AI technologies, many AI-based functions were developed to assist drivers, such as lane changing and parking.

From the perspective of technology development, most intelligent driving technologies, no matter at home or abroad, are at Level 2 or Level 3. AI-based systems and algorithms have become mature, however, the testing of autonomous driving technologies is still at the experiment stage. If autonomous driving cars cause traffic accidents on roads, trust crisis would burst out between auto companies and users. Currently, unmanned freight transport and shared autonomous driving car are the latest AI-based applications.

**Figure 4-15: autonomous driving industry chain**




Source: public information, Deloitte Research

**Unmanned freight transportation.** In logistics sector, autonomous driving can be applied in long-distance truck transportation, delivery on closed roads and intra-city transportation. It can help increase the number of trucks on roads, reduce accident death rate caused by drivers and cut transportation costs. Industry giants and start-ups have started to research the former two application scenarios. Recently, Suning and JD announced the completion of testing on L4 unmanned heavy trucks in China and Silicon Valley respectively.

Trucks have many problems, including large blind area, lack of flexibility, poor stability and loose structure. AI-based unmanned freight transportation can help resolve these problems based on technologies such as multi-sensor online positioning, multi-sensor integration, long-distance sensing, refined modelling & controlling and multi-object optimization and decision making. Commercialized unmanned heavy truck driving technology can reduce driver demands, cut down energy consumption and emission and help mitigate global warming. However, nothing is perfect. Due to high power consumption, battery may cost a lot in long distance transport.

**Unmanned car-sharing.** It's an important application of autonomous driving technology. According to the Report on China's Car-sharing Mobility Market 2018, China's utilization rate of private cars is only 5%, together with some traffic control measures, young urban consumers will increasingly tend to choose car sharing. According to the data released by the Ministry of Public Security in 2017, 215 million of people who hold driving licenses don't have cars, with 33 million new driving licenses being granted every year.

As for the commercial potential of autonomous driving, AI effectively reduces the transportation costs of people and goods. AI ushers us into the era of car sharing. Cars become shared transportation tools from private properties, and car owners become users of car sharing platforms. As young urban consumers increasingly tend to choose on-usage mobility services, rather than purchase their own cars, the current consumption model centered on car ownership will be fundamentally changed. For traditional auto makers, such change will gradually disrupt the business models of traditional auto makers. To response the shock brought by autonomous driving, traditional auto makers including Ford have transformed from car sellers to auto service platforms.

For Internet giants holding with user data, the emerging intelligent transportation market is their future battle field. AI will disrupt the business models of traditional mobility service providers, and the capability of using data to integrate platform resources will be a core competence. The business model that traditional automakers selling car ownership to individuals will be replaced by emerging business models.

### 4.6 Retail: Industry convergence driven by AI

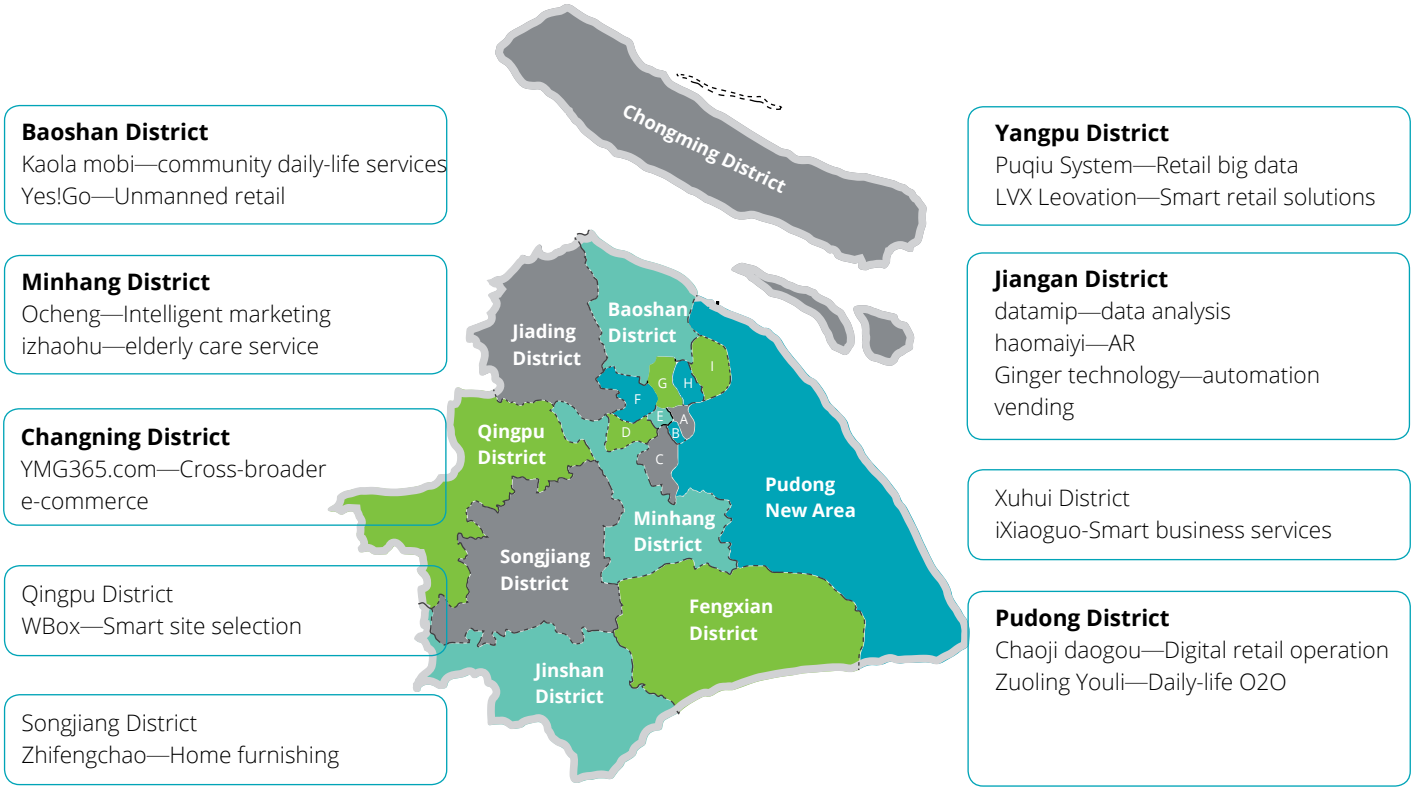
Benefited from the digital transformation of retail industry, AI has penetrated into all the links on the retail value chain. As major retailers enter into the game, e-commerce giants and high-tech companies are stepping up efforts in expanding their presence in the market, driving the convergence of AI applications in retail industry. Deep learning and computer vision have developed as pillar technologies for smart retail. Deep learning is mainly applied in data analytics and modelling to optimize industry chain, while computer vision can be used for consumer behavior analysis and commodity identification. As of now, computer vision-assisted goods detection, self-service checkout, etc. have been commercialized.

Deployment of AI in retail industry is growing rapid across the world. As forecasted by Gartner, 85 percent of consumer interactions will be managed automatically through AI by 2020. Data of Global Market Insights shows an over 40 percent of CAGR for global AI applications in retail industry during 2018-2024, with a market size reaching USD8 billion by 2024. Of which, CAGR of AP market would likely exceed 45 percent, mainly driven by China and India markets. From the perspective of technologies, CAGR of visual recognition/ search related applications would be 45 percent, and that of machine learning related applications would exceed 42 percent.

In this context, the retail industry have been begun to leverage AI to drive transformation. Embracing the trends of technological development, major domestic offline retailers has been increasing their investment in AI. Investment in building AI capabilities by retailers in 2018 stood at around RMB900 million, taking up 3.15 percent of their total investment, and is expected to exceed RMB17.8 billion by 2022, accounting for 25 percent of total investment. E-commerce giants are also utilizing AI to speed up integration of online and offline businesses.

In Shanghai, China's largest consuming city, the application of AI in retail industry would likely drive more efficient growth of the industry. Shanghai has the largest share of AI in retail, and retail technology companies in its Pudong New Area account for a quarter of all its retail companies. Among which, Shanghai Lazhasi Information Science Technology Co., Ltd., parent company of the food delivery brand Ele.me, is located in Putuo District, Shanghai. Tech giants represented by Alibaba and retail champions represented by Yonghui all choose Shanghai as a key pilot plot for their development of new retail and retail technologies. The reason is that Shanghai, as China's most expensive city by consumption per capita, has a strong consumption demand and a higher level of opening up that drive higher degree of acceptance for new retail models among its consumers.

**Figure 4-16: Distribution of key smart retailers in Shanghai**




A Huangpu District B Luwan District C Xuhui District D Changning District E Jing'an District F Putuo District G Zhabei District H Hongkou District I Yangpu District

Source: ITJUZI.com, Deloitte Research

The applications of AI in retail are built based on consumer, goods, store and supply chain, with different focus for different scenarios. Consumer-based applications, including demand forecasting, personalized marketing, purchasing experience and intelligent customer service, aim to continuously attract effective consumer engagement; goods-based applications mainly facilitate payment, stock count, sales promotion, pricing and other features utilizing smart shelves; store-based applications such as site selection, in-store shopping experience and unmanned stores are designed to maximize performance of store investment; supply chain-based applications like smart pricing, intelligent distribution and storage mainly seeks to enhance efficiency.

As AI quickens its penetration into each link of retail industry, topics of concern regarding AI in retail industry in the future will include:

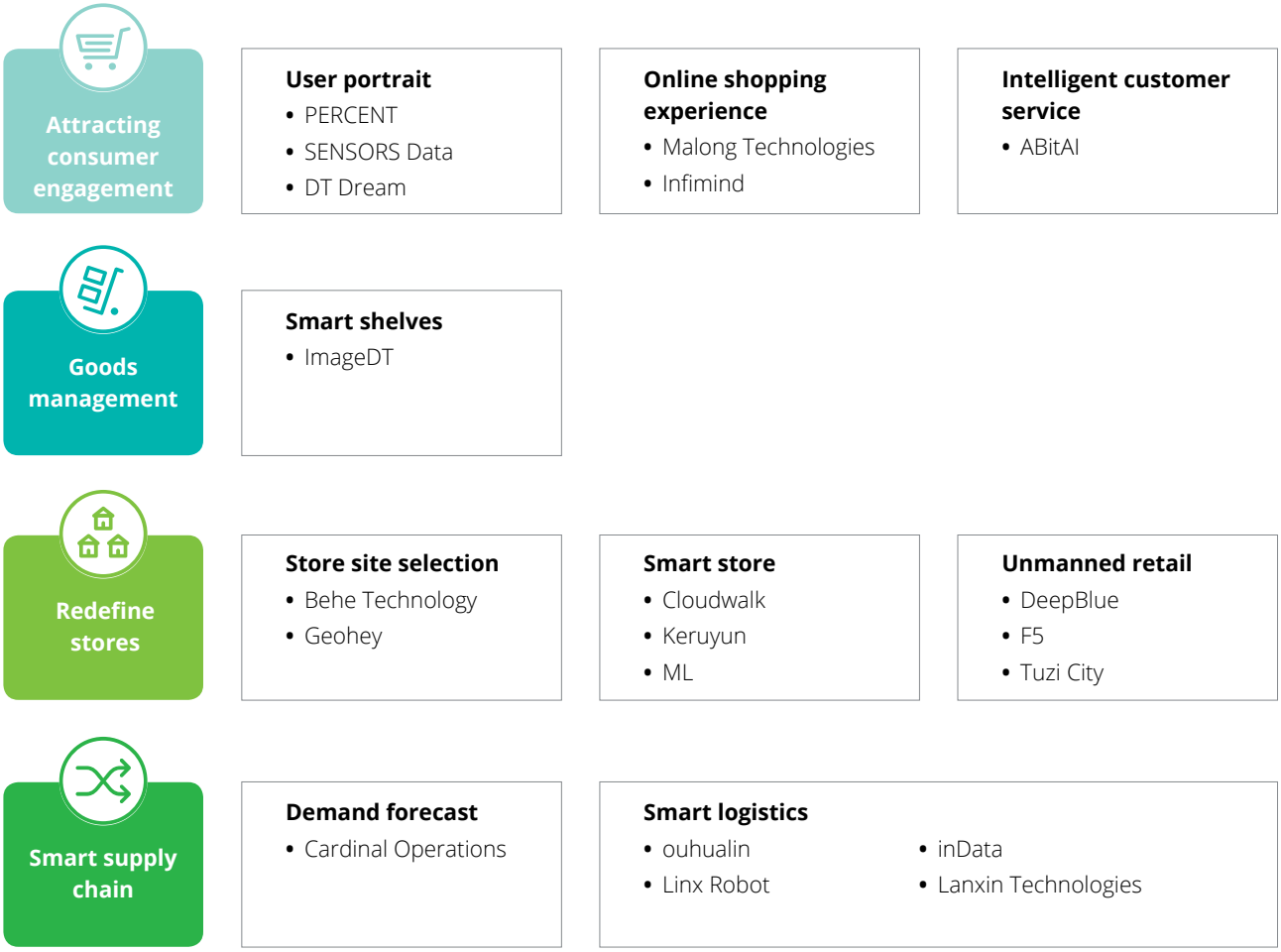
Accelerated online and offline AI integration. AI offers more methods for market players to manage consumer relationships digitally, which will speed up online and offline integration, and enable them to better satisfy consumers' individual needs at customer side as well as further optimize their cost and fees structure to increase income and reduce cost at business side.

Massive fragmented experiments for application scenarios. Diversified development of AI in all links of retail industry brings fragmentation of application scenarios, which now enter into a period of massive experiments. Some applications are developing in an early stage, such as unmanned retail and in-store robots, and have no proof of business to clearly and effectively enhance customer experience and reduce costs. With unclear application scenarios, retailers would also conduct massive experiments with startups to find the best entry point.

Enhanced cooperation between retailers and startups. To compete with tech giants in retail market with extensive application of big data and AI, traditional retailers need to be more proactive in establishing partnerships with startups.

Deep-dive of industry applications by startups. Though with significant investment in AI by tech giants, their competition for ecosystem has not closed the door for startups. However, advantages are limited for startups to compete with tech giants, and they cannot build a moat around themselves merely by export of technologies. Thus, more and more startups would dive deep into the industry, working to offer solutions and build clear profit models for industry clients.

**Figure 4-17: Smart retail industry chain**




Source: Deloitte Research

**User portrait.** Who are the users? What products or services do they need? At what prices? These are the issues most concerned by retailers. The interactions of vendors with customers generate massive data, and through continuous accumulation of users' consumption data and machine learning, vendors could dive deep into the preferences and demands of consumers, and tag each customer with dozens or even hundreds of labels, such as purchase power, consumer credit, brand preference, behavior pattern and social relations, so as to develop corresponding user portraits and knowledge maps. User portraits are the basis for precision marketing and large-scale personalized recommendations and services. Alibaba's intelligent recommendation system made 45.3 billion AI-based personalized recommendations for users during the Double 11 festival last year. Research shows that, sales conversion rates of personalized pages are 20 percent higher than that of traditional pages. PERCENT's user portraits allow vendors to modify user group indicators and weighting, and to choose suitable user groups for marketing. In the marketing project for a large department store, it successfully helped improve performance of promotion activities, reduce the cost of getting new customers by over 70 percent on average, increase conversion rate by more than 70%. Payment as an essential link of consumption contains massive user data. Converged payment analyzes users' payment preferences, habits, frequency, etc. to provide references for vendor to enhance customer loyalty and guide the pace of sales promotion.

**Smart site selection.** China's retail industry has gone from offline to online, and returned from online to the basics of omni-channel development to serve customers. The demand for offline retail is reviving, indicating continuous growth of needs from vendors to open new stores. AI site selection, by integrating various data including legacy sales data, population economic data and distance of competitors, could enhance the granularity of models and analysis of data relevance for site selection to a new level. Site analysis delimits the scope of business circle, and studies real-time pedestrian volume around the pre-selected site as well as changes of people flow within the area, in order to evaluate whether customer flow of the store could be met. Site comparison allows users to pre-select 3-5 store sites and compare their head office of chain stores, sectors, customer flow at different hours, etc. to calculate and analyze the best site for the store. GeoHey leverages geographical big data to offer retailers with site selection for new stores and withdrawal site selection, utilizing machine learning to calculate weighted score for an area or a site based on the features of members of the location, as well as attributes of pedestrians, competitor stores, symbiosis resources for businesses, transportation accessibility, etc. and develop a sales forecast model to predict performance of the store.

**Intelligent customer service system.** AI-based customer service systems starts semantic comprehension and question recognition when customer asks a question, conducts big data search for the question identified, then analyzes the meaning of customer's question and looks into the knowledge map to find matched answers and make decisions. AI customer service answers to customers' questions throughout 24 hours of the whole day to enhance customer satisfaction, and to reduce labor cost for vendors and set people free from dull and intensive tasks to focus on work of higher value. Beebot, Alibaba Cloud's intelligent customer service robot, can handle knowledge enquiries and answer questions based on its knowledge base. Combined with multi-round dialogue configuration tools, Beebot can integrate businesses into dialogues, such as order inquiry, logistics tracking, self-service return of goods, etc. Beebot can serve six million customers per day, with up to 95 percent of resolution rate and 36 industry knowledge bases, providing multi-language services 24/7. ABitAI's Robota leverages autonomous machine learning and human-machine collaboration, based on dialogue model of user intentions and combining with industry knowledge maps, to improve conversion of pre-sales shopping guide and re-purchase. Robota will run within online and offline scenarios, offering pre-sales guide robot and after-sales service robot for online scenario, as well as intelligent hardware robot, offline shopping guide robot, smart shelves, etc. for offline scenario.

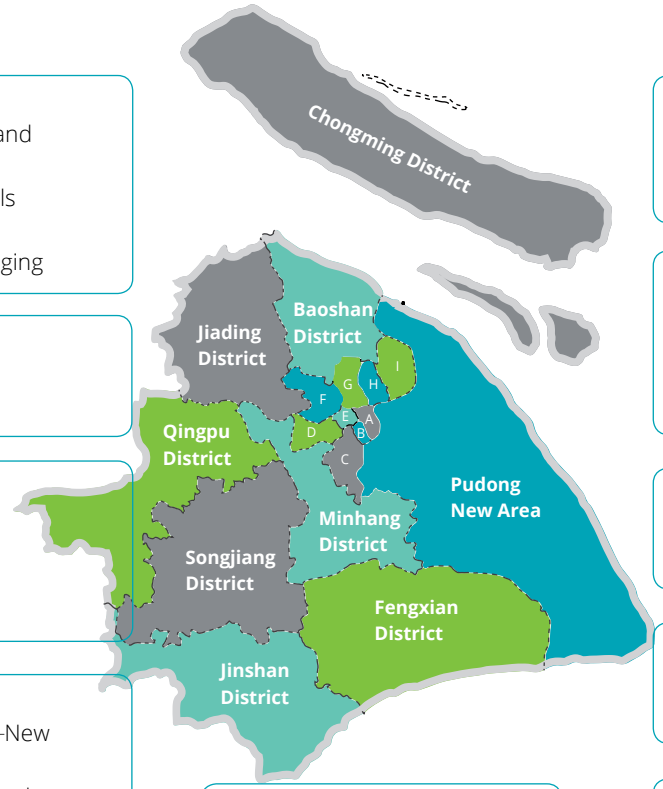

### 4.7 Manufacturing: Huge potentials for application of smart manufacturing

Combined with related technologies, AI could help improve the efficiency of each link of the manufacturing process by collecting various production data via Industrial Internet of Things and processing such data utilizing deep learning algorithms to offer recommendations or even self-optimization. However, compared with financial, business and healthcare industries, the potential for AI application in manufacturing has been substantially underestimated. SAP's analysis of top 300 AI investment projects in China during 2015-2018 shows that 23.4 percent of the investment falls in business and retail sector and 18.3 percent in autonomous driving, while AI investment related to manufacturing stands below one percent, and manufacturing is the sector with the most potentials for AI application scenarios. Research finds that the deployment of AI could help reduce up to 20 percent of processing cost for manufacturers, and up to 70 percent of such reduction comes from higher productivity. By 2030, the world will see GDP growth of USD15.7 trillion driven by AI, of which China would take up USD7 trillion; and by 2035, AI will likely drive an increase of productivity by 27 percent, boosting a manufacturing GDP of up to USD27 trillion.

As guided by state policies, China's manufacturing industry is speeding up its intelligent transformation. The Made in China 2025 plan published in 2015 lists smart manufacturing as one of the five key programs guided by the government. In 2017, China accelerated the implementation of pilots for smart manufacturing, and special subsidies provided for smart manufacturing by the government were also increasing rapidly. In 2018, China implemented 99 new pilot projects for smart manufacturing, of which 18 located in the Yangtze River Delta region and 10 in the Beijing-Tianjin-Hebei region.

As seen from the regional distribution of AI application in manufacturing, Shanghai is growing as a key area for the development and application of emerging smart manufacturing industries. Up to now, Shanghai has basically established a development system for smart manufacturing. In key sectors including automotive, high-end equipment, aerospace, ship and marine engineering as well as electronic information, Shanghai has identified 14 national and 60 municipal smart factories, developed 66 smart manufacturing standards, and recognized 30 smart manufacturing system solutions providers in two batches. With the development of "one center and one belt" smart manufacturing industry cluster, Shanghai is gradually building up a world-class port industrial center and a suburban industrial belt (covering Pudong, Minhang, Jiading, Baoshan, Songjiang and other districts) for smart manufacturing.

**Figure 4-18: Distribution of key smart manufacturing enterprises in Shanghai**




**Jiading District**
ROXZ—Power transmission and distribution
Re-Fire Technology—Fuel cells
RENLE—Industrial control
Luster Teraband—Visual imaging

**Baoshan District**
Ensnmax—Gas detection
Interlway—Industrial robot

**Minhang District**
Celi Engineering—Smart burning
Shanghai Ningyuan—Deep hole machine tool R&D

**Changning District**
China Mingsheng Xinguang—New energy
Estepup Environmnetal Technology—Industrial three wastes

**Jinshan District**
Austri Wind Power—Wind power safety

**Fengxian District**
Huidu Environmental—Recyclable packaging materials
Gehope Environmental—Atmospheric protection

**Yangpu District**
Zhida Technology—Smart charging
Anke Technology—New energy efficiency

**Putuo District**
Shiele Intelligent Technology—Intelligent building
Shunhao Stock—Environmental packaging materials

**Xuhui District**
Basewin Intelligent—Smart equipment
Argus—Prevention&treatment dyes

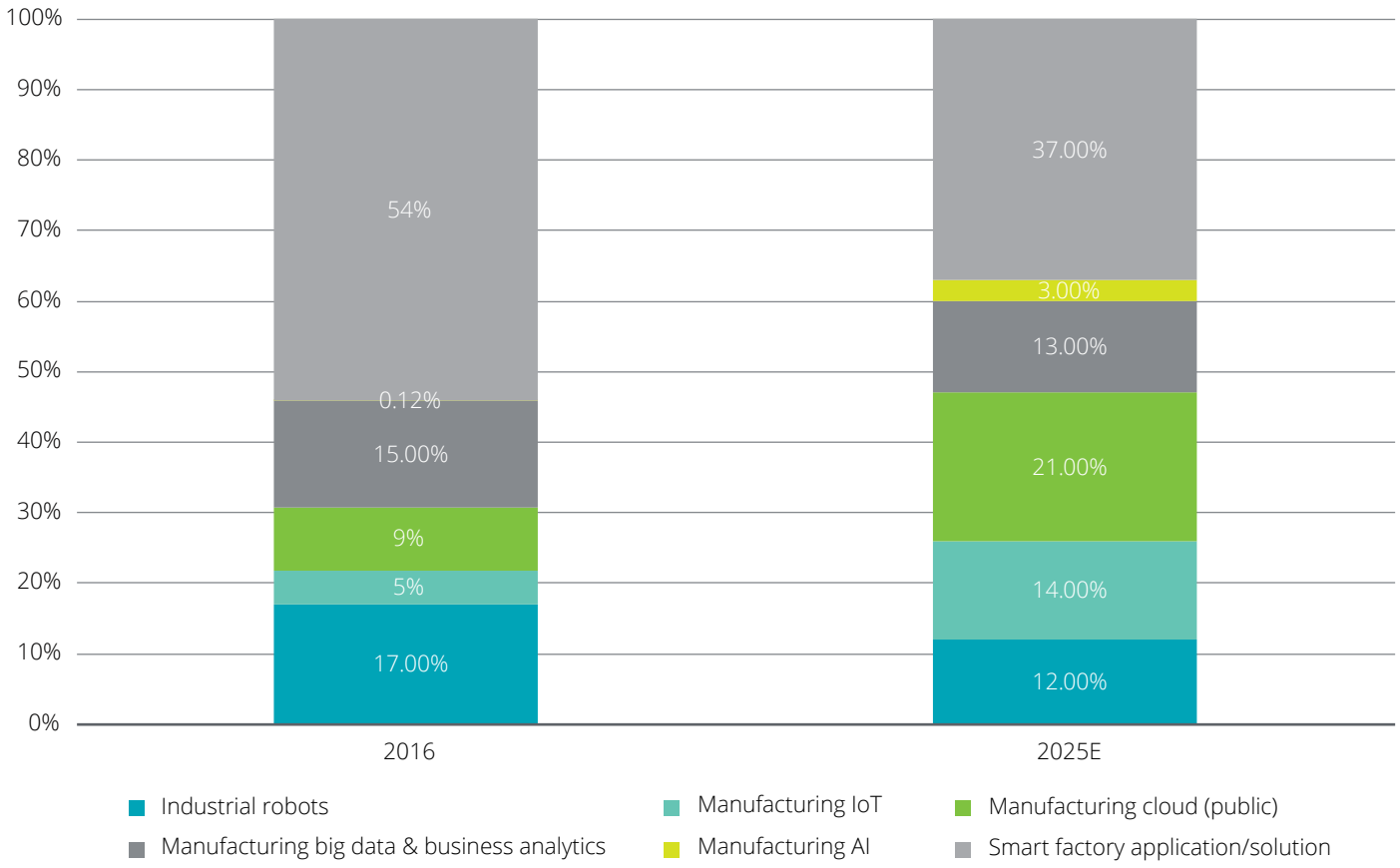
**Jingan District**
Chingmu—Infrared location tracking
FOTRIC—Thermal imaging equipment

**Pudong New Area**
UIROBOT—Industrial automation
Transcom—Silicon solar power
Spreadtrum Conmmunications—Mobile phone chips

A Huangpu District B Luwan District C Xuhui District D Changning District E Jing'an District F Putuo District G Zhabei District H Hongkou District I Yangpu District

Source: ITJUZI.com, Deloitte Research

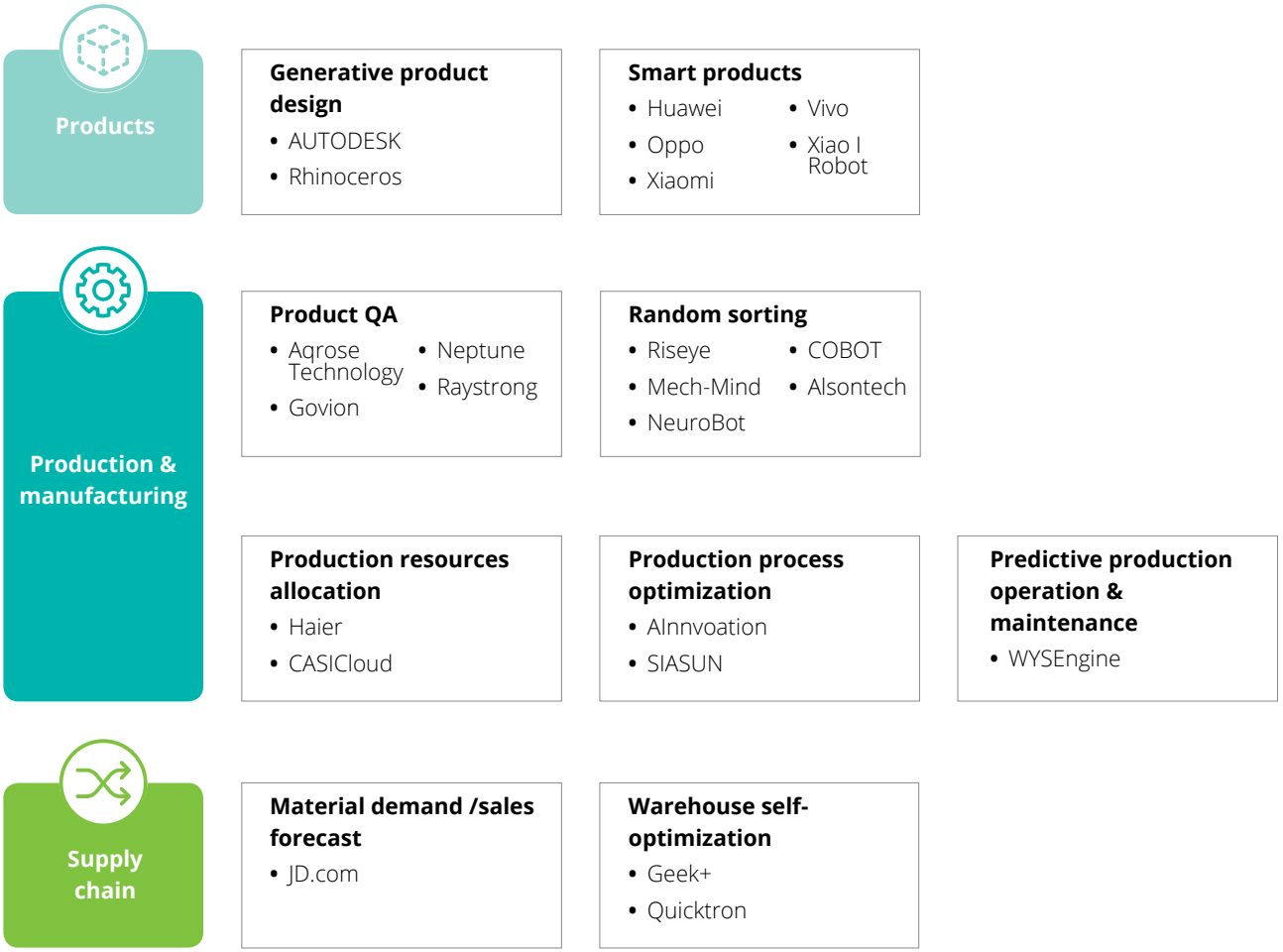
**Figure 4-19: Shares of smart manufacturing segments**



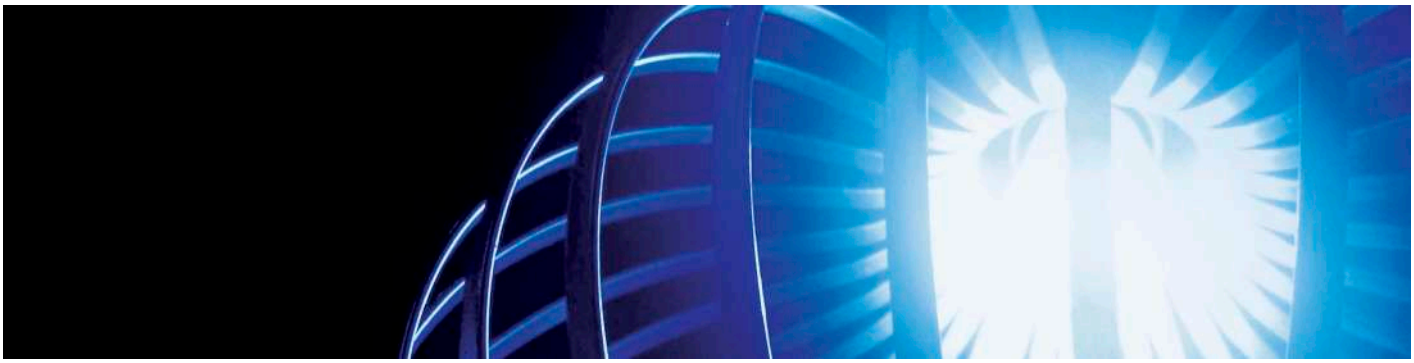

Source: Markets and Markets Insights, Deloitte Research

Manufacturing will become the blue sea for AI applications. The market size for applications of AI and related scenarios in manufacturing was around USD120 billion globally in 2016, and is expected to exceed USD720 billion by 2025, with a CAGR of more than 25 percent.

**Figure 4-20: Smart manufacturing industry chain**




Source: Public information, Deloitte Research



Scenarios of AI application in manufacturing mainly include three categories. First, intelligent products R&D and empowerment of products with intelligence; second, leveraging AI to improve product quality and productivity in manufacturing and management process; third, intelligent development of supply chain.

**Smart products:** Integrate and commercialize AI technological achievements to produce next-generation smart products such as smart phones, industrial robots, service robots, autonomous driving vehicles and drones. These products are the carriers of AI, with the ability to perceive and make judges through combination hardware with various software, and can interact in real time with users and the environment. Take smart phone as an example. In addition to the AI chip that enables it to run and respond faster, smart phone's AI applications including smart voice assistant, biometric identification and image processing also bring multi-dimensional smart experience for the user. Top four domestic phone makers, i.e. Vivo, Xiaomi, Huawei and Oppo, have all launched their AI-featured flagship phones in 2018, indicating huge market potentials for smart products.

**Product quality control:** Machine vision recognition can be utilized to conduct fast scan on the quality of products, enhancing efficiency of quality control. With the ability to keep learning, the performance will be continuously improving over time. Auto parts companies have started to make use of vision systems with machine learning algorithms to identify defective parts, including detecting defects that are not covered in the data sets used for training algorithms. AI vision technology company Bosaidong can detect defects on the exterior of auto electroplated parts with a high precision of 0.1mm; Aqrose applies AI and 3D vision technologies in industrial quality control and sorting, and completed an A-round funding raising of USD8 million in January 2018; Govion uses AI vision in quality control of screens, and has completed an A-round funding raising of RMB50 million; Raystrong focuses on the quality control of textile fabrics.

**Warehouse self-optimization:** Smart carrier robots has significantly enhanced sorting efficiencies in warehouses and reduced labor costs. Take handling system as an example. The system assigns handling tasks based on production demands, and the robots will complete point-to-point goods handling automatically. Robots transporting goods within a factory or warehouse would detect obstacles and adjust moving routes to find the best routes. Machine learning algorithms would use logistics data, such as data of materials in and out, stocks, turnover of parts, etc., to facilitate self-optimization and operation of warehouses. For example, algorithms may suggest to relocate parts with low demands further away, and place parts with high demands in surrounding areas with quick access. With focus on logistics robots and smart logistics solutions, Geek+ develops robotic sorting systems, handling systems and sorting systems, leveraging robotic products and AI technology to offer smart logistics automation solutions. Robotic handling system utilizes moving robots to handle shelves/trays for automatic handling, facilitating smart transformation with enhanced flexibility of production, and achieving automatic route planning and loading/off-loading of shelves/trays for unmanned, smart handling within factories and workshops.

### 4.8 Smart city: AI-based urban infrastructure innovation system

Different AI application scenarios are integrated in a city. With the application of AI and other cutting-edge technologies, urban infrastructure are upgrading, fully supporting the construction of intelligent cities. While urbanization is accelerating, cities are facing many development challenges such as dense population, energy structure relying on limited energy types, low efficiency of resource distribution, risky transportation and logistics, low garbage recovery rate and poor air quality. These problems have stimulated the development of AI industry.

As increasing urban population brings challenges for urban space and resources distribution as well as safety and life quality, dense urban population is a compelling problem. China adopts an energy structure relying heavily on traditional energies such as coal and natural gas. In response to the Paris Agreement on climate change, China has vowed to put a peak on its growing carbon dioxide emissions by the year 2030. The world is paying increasing attention to climate improvement through energy structure changes. The traditional independent network of resources distribution has caused vast problems concerning urban infrastructure construction including unreasonable use of underground space, environmental destruction caused by repeated construction, potential danger from aging pipelines and lack of accurate operation and maintenance data. As an effective solution to pipeline-space conflict, utility tunnel is still in need of improvement in systematic planning and reasonable charging mechanism. Logistics is subject to high risks due to heavy reliance on manual sorting and distribution. Therefore, it is necessary to integrate technologies including big data, cloud computing and IoT with urban infrastructure construction to create innovative approaches to logistics resources distribution. Such initiatives are expected to facilitate the application of information and intelligent technologies in logistics and the establishment of standards and systems in the industry. China is lagging behind in waste sorting and recycling, compared with developed countries, exposed to various obstacles to hazard-free treatment, recycling and reduction of urban life wastes. These obstacles include waste recycling disorder, ineffective waste sorting and collection, rough garbage disposal and closed management system. Extensive and long-lasting air pollution in China is threatening people's health and may bring serious economic loss and pressure to healthcare system. Air quality control has become a matter of concern for the society.

As one of the technologies to support the construction of smart cities, AI can be applied in urban infrastructure system to address a series of city development challenges and create healthy, low-carbon, safe and convenient city life. The application of AI can be piloted in key projects and then expanded to cover all areas to establish an AI-based urban infrastructure innovation system.

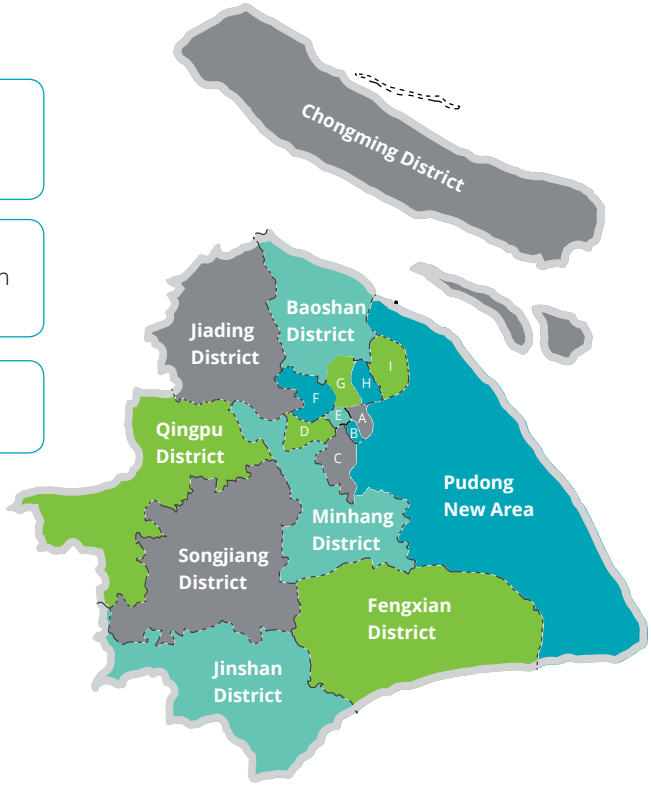
Shanghai is taking active initiatives to establish a global leadership in AI development, with great investment in the development of comprehensive projects including Xuhui West Bound AI Tower, Zhangjiang AI Island, Maqiao Artificial Intelligence Innovation Experimental Zone, Beiyang AI Town, Jiading Next-generation Data and AI Research Center and Dongjing AI Industrial Base. These projects can provide complementary advantages in AI innovation resources and industrial base. For example, Maqiao Artificial Intelligence Innovation Experimental Zone, which consists of industrial innovation development zone and comprehensive practice zone, will establish extensive AI application scenarios to support urban management, social governance and livelihood service, etc., helping Shanghai establish a leadership in AI development.

**Figure 4-21: Distribution of comprehensive zones in Shanghai**

**Xuhui District**
West Bound AI Tower
Beiyang AI Town

**Jiading District**
Next-generation Data and AI Research Center

**Songjiang District**
Dongjing AI Industrial Base




**Pudong New Area**
Zhangjiang AI Island

**Minhang District**
Maqiao Artificial Intelligence Innovation Experimental Zone

A Huangpu District B Luwan District C Xuhui District D Changning District E Jing'an District F Putuo District G Zhabei District H Hongkou District I Yangpu District

Source: ASKCI Consulting, Deloitte Research

The urban infrastructure system that applies AI mainly includes urban green space, transportation, logistics, circulation, energy and other innovative systems.

**Green space system (intelligent water treatment-based park):** Green space system refers to an urban intelligent water management system built for real-time response to the impacts of global climate changes on the urban water environment and ultimately achieve the goal of water saving and recycling, environmental adaptability and safe use.

During the implementation, sponge city and rain garden technologies should be deployed first in the urban comprehensive zones combined with urban smart comprehensive corridors to build a more mature operating and management models of the sponge city. Additionally, the green space system can be integrated with sewage and waste disposal system and energy system to fulfill the principle of circular economy. And it can be further expanded to the whole city to ensure that the city is able to navigate the water environment crisis led by global warming through various measures.

**Transportation system (user-friendly mobility):** In the future smart city, the needs of human and city will be taken as a starting point to actively respond to the development of future AI technologies, build various application scenarios for smart transportation and create a more effective, dynamic and sustainable smart mobility system.

When it comes to implementation, in terms of AI' technological path in transportation, a new-type road classification system can be used in the comprehensive zones in the near term to change the density of road networks and road sections. Besides, vehicle-infrastructure cooperative technology and smart parking technology can be also used to build smart scenarios for sharing mobility and self-driving taxi system in a small range. And it can be expanded to the whole city in the future.

**Logistics (automated flow):** The logistics system with automated flow process aims to lower costs and raise efficiency and safety. It applies automated and intelligent technologies to address the issue of "last mile" delivery, enhance logistics and delivery efficiency, lower costs and significantly improve street and traffic environment.

The case of Netherlands' urban underground pipeline network can be used as a reference to specific practices. In the near future, pipes for underground logistics systems can be reserved in the urban comprehensive zones for installing wireless charging infrastructure. And a small range of test run is implemented based on mature supporting technologies. In the medium to long term, the city can work with established logistics companies to design a robot distribution system and build on existing technologies to develop technologies that can extend the networks of underground logistics system to the whole city.

**Circulation system (solid waste treatment):** It is aimed at achieving recycling, reducing and harmless solid waste treatment to reduce greenhouse gas emissions in the city and improve the utilization of recyclable resources with facilities and technologies including pneumatic automation system and waste sorting center.

In the near term, urban comprehensive zones can build intelligent waste sorting and anaerobic digestion of organic waste power generation systems and pneumatic conveying system and kitchen waste disposal system for dry and wet wastes, and integrate with intelligent waste information monitoring and management network for better control and operation. In the medium to long run, incentives can be introduced in the production and pre-sorting of wastes to control sources and expand to the whole city.

**Sustainable construction (energy system):** Building a sustainable energy system aims to improve efficiency, flexibility and reproducibility and achieve resources saving and recycling by leveraging technologies including distributed energy, waste water heat recovery pump, combined cooling heating and power, microgrid and energy storage technology.

In the near term, urban comprehensive zones combine waste water heat recovery pump and waste incineration power generation technologies to create an energy chain that is aligned with the principle of circular economy. Renewable energy, including solar energy and wind energy, can be provided for the starting zone first and distributed energy for integrated functional areas. And the use of renewable energy can be extended to the whole city in the medium to long run.

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