Hype Cycle for Smart City and Sustainability in China, 2023

Published 20 July 2023 - ID G00790987 - 113 min read

By Analyst(s): Milly Xiang, Uko Tian, Kevin Ji

Initiatives: Digital Technology Leadership for CIOs in China; Government Verticals Digital Innovation and Application Modernization

China is promoting intelligent and sustainable urban design, operation, and services by utilizing digital technologies to benefit residents and businesses. This research helps CIOs of governments and urban ecosystem partners assess technologies to achieve societal and sustainability outcomes.

More on This Topic

This is part of an in-depth collection of research. See the collection:

- 2023 Hype Cycles: Deglobalization, AI at the Cusp and Operational Sustainability

Analysis

What You Need to Know

In early 2023, the State Council of the People's Republic of China released the Plan for the Overall Layout of Building a Digital China. The plan proposes that, by 2025, the building of a digital China should see major progress, with the fundamental parts of a strongly coordinated integrated societal system that is horizontally and vertically linked taking shape. It specifies that smart cities have become important engines for economic recovery and sustainable development, leading the city economy to encounter a new stage of strategic transformation toward a digitally empowered one. On top of digital infrastructure and data asset, the forthcoming technologically enhanced "digital" economic system focuses more on:

- Highly efficient and collaborative governmental services through digital capability and service innovation, as well as accelerated system and regulatory improvement
- An inclusive, equal and convenient digital society (urban and rural) through digital public service, secure and reliable data exchange and governance, and urban and rural development
- Green and intelligent urban ecosystems through environmental governance, natural resource digitization, and green and smart lifestyle.

This year's Hype Cycle for Smart City and Sustainability in China highlights technology innovations that are critical to empower this plan. CIOs of governments and urban ecosystem partners must stay up to date with government initiatives and use cases powered by these technological innovations to determine their impact and the opportunities they present.

The Hype Cycle

This Hype Cycle is designed to help CIOs in government and the urban ecosystem evaluate emerging trends and technologies in terms of their maturity and impacts on smart city and sustainability initiatives. This year, the technological innovations on this Hype Cycle are aligned to the following four pillars that empower smart city initiatives:

- Critical city infrastructure and services — This pillar notes how technology-enabled new and upgraded civil infrastructures, such as transportation, building, parking, street poles, and city assets and infrastructure, can drive city administration and service efficiency with optimized citizen experience. It also includes new ways of managing cities using digital twin and delivering interjurisdictional government services.
- Digitally enabled sustainability — This pillar looks at how digital and sophisticated tools such as analytics, AI, Internet of Things (IoT) and machine learning help mitigate environmental impacts and carbon footprints, manage autonomous sustainability and industry/cross-industry ecosystem performance, and enhance city resilience with adaptation initiatives.
- Enabling digital technologies — This pillar lists fundamental technical elements to empower combinatorial innovation that is required in every smart city. When combined, these technologies give rise to new use cases and trends, and form a mature smart city solution.
- Data-driven ecosystem based on trust — This pillar illustrates the fundamental data-related initiatives and activities to form trusted and collaborative urban ecosystems within smart cities.

In addition to the innovations we already tracked, two new technologies have been added to the Hype Cycle this year. This is to reflect the technological innovation that is critical for the data as a key asset to empower the smart city ecosystem and digital economy:

- Data governance, which targets to build a data life cycle framework around standards, policy, ownership, authorization and technical implementation of data ecosystem
- Data risk assessment, which focuses on effective implementation of data security and privacy controls to mitigate risks

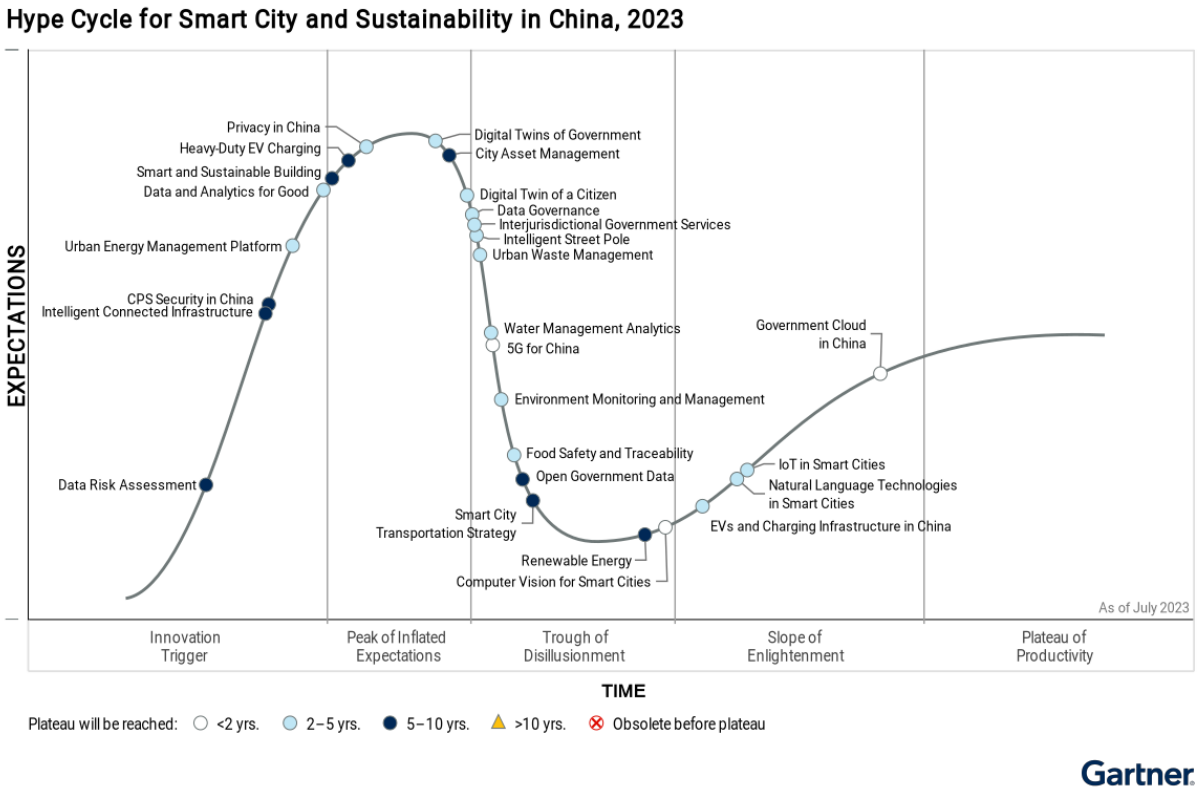
We have also renamed three innovations to reflect better alignment with the themes and trends:

- Smart building revised to smart and sustainable building due to the growing focus on sustainability throughout the entire building life cycle.
- Green energy revised to renewable energy to align with Gartner's updated research terminology.

- Underground infrastructure management revised to city asset management to reflect a broader representation of a variety of city assets and infrastructure.

With these changes, we believe this year's Hype Cycle better addresses clients' interests and provides a comprehensive view of the technologies specific to China's market. Some of the key enabling technologies, such as government cloud in China, IoT in smart cities, and natural language technologies in smart cities, gain momentum toward the Plateau of Productivity. Use cases empowered by combination of these technologies are still heading toward the Trough of Disillusionment due to a shift of focus on proof of value instead of proof of technologies, due to an increasing focus on outcomes and business value setting the stage for moving toward the Plateau of Productivity. Use cases aligning to green and sustainable cities are gaining momentum, accelerating the descent from the Peak of Inflated Expectations. Most of these use cases will reach the Plateau of Productivity in the coming two to five years. Digital twins of government, CPS security in China and data-related initiatives have moved further toward Peak of Inflated Expectations but remain above five years to mainstream impact.

Figure 1. Hype Cycle for Smart City and Sustainability in China, 2023



The Priority Matrix

The Priority Matrix illustrates the immediate and future opportunities for different technologies based on their potential impact and maturity. While working across the entire urban ecosystem and investing to drive smart cities initiatives, CIOs of government organizations and urban ecosystem partners should prioritize technological innovations that introduce transformational and high benefits to cities. For example, IoT and computer vision for smart cities bring transformational benefits to smart cities, empowering a wide range of applications across urban ecosystems, and they are expected to mature within five years. 5G for China and government cloud in China are high-impact technologies and are the foundation for multiple use cases in smart cities. Digital twins of government support discrete, composite and organizational deployment within cities and bring high impacts in both department level and citywide operations. Use cases like environment monitoring and management, and urban waste management are introducing high benefits in terms of operational, financial and sustainability outcomes.

While other technology solutions and initiatives — such as renewable energy, smart and sustainable building, and intelligent connected infrastructure — are transformational or high-impact strategies, they are expected to mature in a five-to-10-year time frame. This implies that governments and urban ecosystem players cannot reap benefits and high/transformational impact in shorter time frames. These solutions offer high risk-reward benefits and require careful planning and prioritization as governments and urban ecosystems exploit the potential benefits of these technologies. Some technologies are composites and consist of multiple elements or systems of systems, which require a big collaborative effort across different government departments and industry sectors, as well as interoperability and standardization. This complexity brings uncertainty to technology adoption speed and evolution.

Table 1: Priority Matrix for Smart City and Sustainability in China, 2023

(Enlarged table in Appendix)

Benefit ↓	*Years to Mainstream Adoption*			
	Less Than 2 Years ↓	*2 - 5 Years* ↓	*5 - 10 Years* ↓	*More Than 10 Years* ↓
Transformational	Computer Vision for Smart Cities	IoT in Smart Cities	Data Risk Assessment Renewable Energy Smart and Sustainable Building	
High	5G for China Government Cloud in China	Data Governance Digital Twin of a Citizen Digital Twins of Government Environment Monitoring and Management EVs and Charging Infrastructure in China Food Safety and Traceability Intelligent Street Pole Interjurisdictional Government Services Natural Language Technologies in Smart Cities Privacy in China Urban Energy Management Platform Urban Waste Management Water Management Analytics	City Asset Management CPS Security in China Heavy-Duty EV Charging Intelligent Connected Infrastructure Open Government Data Smart City Transportation Strategy	
Moderate		Data and Analytics for Good		
Low				

Source: Gartner (July 2023)

Off the Hype Cycle

We removed the following technologies from the Hype Cycle:

- Energy-water nexus, and urban sustainability and COP 21 — these two innovation profiles remain in the 2023 smart city technologies and solutions Hype Cycle, and we don't see a big difference for positioning and maturity in China.
- Smart parking was phased off the Hype Cycle, as it advanced rapidly to become a well-established technology and scaled beyond the Plateau of Productivity.

On the Rise

Data Risk Assessment

Analysis By: Anson Chen

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Definition:

Data risk assessment (DRA) is a process used to review whether data security and privacy controls are implemented effectively and satisfy an organization's risk appetite across all applicable security products and applications. These controls aim to mitigate business risks, such as noncompliance with regulations, infringements of privacy and data breaches.

Why This Is Important

China's continuing expansion of digital business initiatives and tightening regulatory oversight on data security governance (DSG) have made DRA a required part of assessing how business risks need to be mitigated. DRA analyzes gaps and inconsistencies in DSG policies stemming from controls applied by data security, privacy and identity management products. A DRA is fundamental to DSG's successful implementation and compliance with laws and sector-specific regulations.

Business Impact

A DRA provides insights to security and risk management (SRM) leaders on prioritizing data risks against the organization's risk appetite. It helps leaders design informed risk treatment strategies by identifying deviations in the implemented data security policies and assessing financial business impacts. Conducting DRA aids in fulfilling China's legal requirements in data processing and other sector-specific regulations (e.g., in finance, telecom, government and automotive).

Drivers

- China's national data economy initiatives and regulatory requirements drive public and private organizations to expand DRA's impact evaluation to national security and public interests (e.g., healthcare, transportation and utilities). This happens when important data, a large volume of personal information and cross-border data transfers are involved in the organization's business transaction activities.
- Backed by business leaders, DRA enhances business outcomes by addressing data risks that directly affect business risks, while identifying and evaluating data access needs for business users.
- The financial DRA (FinDRA) process enables business functions to make informed decisions regarding the data security budget. This is done by assessing the financial impact on the business and determining the optimal level of risk mitigation aligned with budgetary limitations and its impact on business outcomes.
- Every decision to mitigate a business-related data risk requires a DRA to establish how each risk might evolve. It also requires a data classification process that can identify data in structured and unstructured formats and leverage security, privacy and business metadata.
- The need to create a data map and undertake DRA analysis with data security posture management (DSPM) products enable the assessment of privileges provided to each user or machine account against the data in scope.
- The creation of a data risk register relies on executing the DRA process and implementing a data-centric security architecture (DCSA) approach. The register is designed to contain assessments of how gaps and inconsistencies in data security controls can lead to business risks.

Obstacles

- Diverse compliance requirements from different regulators demand that a DRA be characterized by different risk vectors. It includes full-scope data security risks, data outbound transfer risks, privacy and technical vulnerabilities. These risk vectors complicate the implementation of a DRA, and make manual DRA processes difficult to fulfill.
- Completing DRA processes requires expertise from different experts and an assessment of the effectiveness of deployed security controls, which is often difficult to acquire.

- Data processing activities evolve with changes in business processes. Point-in-time DRA will not suffice to identify data security risks promptly and sustainably.
- A DRA will succeed only if business leaders support the need for data security controls. However, most organizations in China struggle with insufficient engagement from business and without a successful engagement of stakeholders through a DSG.

User Recommendations

- Adopt process automation to streamline arbitration of DRA processes and generate report templates to address various DRA compliance requirements.
- Employ DSPs or DSPMs to enable DRA as part of routine data security operations.
- Leverage a Data Security Steering Committee (DSSC) to work with all stakeholders facilitating DRA, drawing on committee members' direct knowledge of and insights into business outcomes, business projects' requirements to process datasets and the impacts of business incidents.
- Identify data risks that are not mitigated — e.g., inadequate data residency controls and inconsistent data activity monitoring — and evaluate how these might create business risks and prioritize risk mitigation measures.
- Communicate DRA findings to central enterprise risk management (ERM) and DSSC through a DSG framework to gain business support for changes to staffing and budgets.

Gartner Recommended Reading

Security and Risk Management Leaders' Guide to Data Security in China

Prepare for the Security Assessment of Outbound Data Transfers From China

Innovation Insight: Data Security Posture Management

A Data Risk Assessment Is the Foundation of Data Security Governance

Use the Data Security Governance Framework to Balance Business Needs and Risks

CPS Security in China

Analysis By: Angela Zhao

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Definition:

Cyber-physical systems (CPS) are engineered systems that orchestrate sensing, computation, control, networking and analytics to interact with the physical world (including humans). When secure, they enable safe, real-time, reliable, resilient and adaptable performance.

Why This Is Important

Driven by the “digital economy” and “new infrastructure” initiatives, CPS underpins critical infrastructure and sectors, such as transportation, energy, medical care and government affairs. However, there are both legacy infrastructures that were deployed years ago without built-in security and new assets, which are also full of vulnerabilities. It is imperative to improve CPS security by establishing a systematic security protection system to reduce security risks.

Business Impact

CPS, such as operational technology and Internet of Things, are one of the key components in China’s digital economy and the 14th Five-Year Plan. Security incidents of CPS could affect citizens, organizations and a government’s finance, authority, survival and reputation. Impacts range from breach of personal privacy and safety to the disruption or failure of critical functions, e.g., traffic paralysis, power outage, and medical system failure.

Drivers

- Multiple CPS security-related national standards have been published in China in the recent years, such as The Multi-Level Protection Scheme (MLPS 2.0), GB/T 37971-2019 on Framework of Smart City Security Systems, GB/T 41400-2022 on Industrial Control System Information Security Protection Capability Maturity Model. These standards emphasize CPS security's importance in supporting mission-critical domains from the government perspective.
- The consequences of a CPS security incident go beyond cybersecurity-centric data loss, to include operational shutdowns, environmental impacts, damage and destruction of property and equipment or even personal and public safety risks.
- China is one of the leading countries to develop smart cities. A large number of smart terminals and sensors are connected to the integrated network of the smart city, so CPS are becoming ubiquitous, making them an ideal target of malicious attacks.
- The deployment of AI and IoT sensors technologies involve large amounts of personal and business data and represent an uncharted risk territory. This creates privacy concerns from citizens and partners who expect their data in good custody, and CPS security solutions are needed to ensure the data is well-protected or securely processed.
- The various types of CPS and protocols result in complex and diverse access methods. Unified and effective CPS security management of not only the terminals but also the interfaces of data transmission is needed, to address the risk of information leakage, data eavesdropping, illegal hijacking and tampering.

Obstacles

- CPS are often deployed by business units without consultation with the security team. Lack of overall planning, sufficient resources, cross-department collaboration and clear roles and responsibilities on CPS security management.
- CPS usually composes multiple layers of hardware, software and networks and different protocols, which makes it complex to identify and manage security risks.
- Many CPS in China were designed and deployed before security considerations became a priority, making them vulnerable to attacks. Upgrading or replacing these legacy systems can be difficult and expensive. Many devices lack storage and compute power to facilitate security mechanisms.
- The overall awareness of CPS security management is prioritizing cyber over physical. Physical security is sometimes not addressed enough.
- Though with the existing government standards in place, there is currently a lack of widely accepted standards for organizations to assess and compare security solutions.

User Recommendations

- Educate business executives of the importance of CPS security to digital business initiatives.
- Establish a CPS security governance model, including a steering committee with all stakeholders' involvement, a reasonable organizational structure, and formalized roles and responsibilities.
- Develop, recruit or purchase sufficient competencies for dedicated CPS security management.
- Incorporate security in the full life cycle from development to deployment and ongoing maintenance. For legacy vulnerabilities that cannot be mitigated in a short-term, implement compensating controls such as access control, intrusion detection and prevention, encryption, and network segmentation.
- Evaluate physical security risks such as physical access breach, asset loss and wireless network interference, and implement corresponding controls and monitoring systems.
- Inventory existing CPS security solutions and evaluate the growing list of solutions with identified generic and vertical-specific use cases.

Sample Vendors

360 Digital Security Group; DAS Security; H3C; Huawei; NSFOCUS; QAX; Tianfang Sec; TOPSEC; Venustech

Gartner Recommended Reading

CPS Security Governance — Best Practices From the Front Lines

Predicts 2023: Cyber-Physical Systems Security — Beyond Asset Discovery

Tool: Cyber-Physical Systems Protection Platform Rating and Selection

Intelligent Connected Infrastructure

Analysis By: Shivani Palepu, Ivar Berntz, Jonathan Davenport, Venecia Liu

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Definition:

Intelligent connected infrastructure (ICI) is a combination of technologies integrated in a mesh fabric to enable the infrastructure to do a data exchange with surrounding entities in an ecosystem, such as vehicles, technicians and equipment. The mesh is made up of elements such as AI, Internet of Things (IoT), cloud, analytics, edge computing, telecommunications and autonomous technologies. The transportation infrastructure can include ports, bridges, roadways, railways, airports and airways.

Why This Is Important

ICI can be used to orchestrate an operational environment that can link physical and digital assets with data to enhance communications. ICI can improve business operations to achieve better safety, less congestion, shorter wait times and better asset utilization. Stand-alone technologies, such as IoT or AI, have provided some benefit to the industry. However, a force multiplier can be achieved when technologies come together to communicate and exchange data to provide combined insights.

Business Impact

There are operational and service benefits to ICI. For example, ICI could improve port terminal operations whereby cranes, Automated Guided Vehicles (AGV), cargo, rail and trucks could exchange real-time data and status updates. Airports could benefit from an increased capacity and reduce the aircraft turnaround time through better orchestration, coordination and communication. Cities could move more vehicles through intersections with dynamic traffic light timing and reduce traffic congestion.

Drivers

- Transport entities are under pressure to alleviate supply chain bottlenecks. ICI can help developing more-efficient operations using a combination of technologies.
- There is a need for visibility and transparency of asset location and data to optimize operations. ICI combines diverse data sources to provide a more holistic view. ICI enables and empowers cross-ecosystem collaboration among transport assets.
- Ability to do remote maintenance and predictive maintenance of urban infrastructure and equipment before failures and accidents occur, such as the derailment of track from an overheated wheel bearing.
- Reduce operations cost and reduce turnaround times with efficient operations.
- Ability to monitor and notify drivers, passengers, operators of real-time situational data. Communicate relevant information utilizing data insights for timely action.
- The drive to build an intelligent urban ecosystem and enhance resident satisfaction.

Obstacles

- ICI requires digital mesh collaboration to be realized across the transportation infrastructure and across various technologies in the ecosystem.
- Technology standard alignment between infrastructure and vehicle. Challenges on technology integration, technologies standards, communication protocols as well as integrating data from various sources.
- The cost of integration of legacy systems is high.
- The investment to tie all the technologies together is challenging, and it requires coordination by various entities with different reporting structures and goals.
- The risk level is high. New technologies offer new possibilities but also come with unknown risks. For example, absence of standards and immature technologies can lead to unintended consequences and can facilitate hacking.
- Cybersecurity concerns for an integrated system, such as operational technology (OT) and IT technologies.
- There are privacy concerns on personal data use and thus, adoption of ICI might be challenging.

User Recommendations

- Identify stakeholders in your ecosystem who could benefit from better data insight, such as truck drivers waiting for unloaded cargo, pilots, tugboats, crane operators, rail cargo, shipyard equipment, shippers and emergency services.
- Assess existing data sources, and identify areas where data collection (such as maintenance, planning, forecasting, safety and traffic flow) can impact other business operations.
- Build a technology roadmap with this ICI vision to ensure edge computing or 5G implementations can be leveraged in multiple ways as a data exchange to multiple stakeholders.
- Consider adopting a composable business architecture for agility and tap into a data exchange platform to minimize the cost of building everything from scratch.

Sample Vendors

Alibaba Cloud; Bosch Group; Huawei; NTT Group (NTT DATA); Siemens Mobility

Gartner Recommended Reading

Tool: Connected Vehicle Use-Case Opportunity Assessment

Seize the Technology Advantage With Combinatorial Digital Innovation

Urban Energy Management Platform

Analysis By: Uko Tian

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

An urban energy management platform (UEMP) provides user-centric views of multiple sources of energy consumption, such as electricity, gas, heat and water. In addition to supporting government policy decisions on energy efficiency and carbon emissions, UEMP provides insight for users to reduce energy costs and improve efficiency as well as for energy suppliers to make production and business decisions.

Why This Is Important

Improving energy efficiency and reducing carbon emissions are local governments' top priorities. UEMP enables real-time analysis and pattern recognition in energy consumption, helping governments to make accurate and timely decisions to drive clean energy transition. UEMP can combine smart initiatives in transportation, buildings and urban development to create far-reaching value for urban sustainability. The platform also creates value for all participants by connecting energy users and suppliers.

Business Impact

The primary business impacts of UEMP are:

- City governments can closely monitor the energy consumption of key enterprises and formulate energy policies in a timely manner to ensure carbon emissions reduction and clean energy transition.
- Energy production and distribution companies can use UEMP to plan production, optimize distribution, set prices and improve service quality.

- Based on UEMP's user-centric analysis, heavy energy users can reduce energy costs and develop practical ways to reduce carbon emissions.

Drivers

- **Need for city-level energy management to achieve national top-down carbon reduction target:** Sixty-five percent of China's population lives in urban areas and consumes four-fifths of total energy, so city-level energy management is essential for achieving the national energy transition strategy. Efficient energy consumption models at the city level will directly contribute to meeting national carbon reduction targets.
- **Need to optimize energy use patterns:** The uneven distribution of energy creates imbalances between supply and demand at the regional level. Ensuring energy supply for economic growth while controlling carbon emissions requires local governments to optimize energy use patterns by improving the digital footprint of multiple entities.
- **Corporate sustainability goals:** Improving energy efficiency and increasing the proportion of green energy in total energy consumption is an important part of corporate environmental, social and governance (ESG) goals.
- **Increasing adoption of smart meters:** Smart meters and advanced metering infrastructure are being widely deployed, laying the foundation for real-time collection of energy usage data.

Obstacles

- Data sharing faces many challenges, including vertical management of various energy suppliers (electricity, water and gas), lack of support from people in power and enterprises' unwillingness to participate.
- There is no clear answer to who the platform operator is. This is a result of multiparty games and may vary from city to city. Most likely, it will be a government-backed third-party entity responsible for building and running the platform. Still, the decision process about the operator will slow down the rollout of UEMP.
- UEMP needs to be tailored to each city's needs. This requires platform operators to collaborate with their IT vendors to build solutions by integrating different technologies such as cloud, Internet of Things (IoT) and artificial intelligence/machine learning (AI/ML).
- As there is currently no leading provider focused on UEMP, the solution still remains immature. The immaturity of the solution and no clearly defined expectations increase construction costs and the risk of failure.

User Recommendations

- Build energy service capabilities to provide governments and energy-intensive customers with suggestions to reduce costs and improve the environment. Platform operators need to build holistic energy consumption data and user-centric visibility to achieve business success.
- Involve the city leaders and top management. Municipal governments need to push the top-level design of UEMP and facilitate data sharing and governance among multiple entities, from energy providers to consumers.
- Leverage information from the UEMP to optimize energy consumption plans to meet enterprises' ESG goals.

Gartner Recommended Reading

Market Guide for Energy Management and Optimization Systems

Market Guide for Commercial and Industrial Energy Management and Optimization Systems

Energy CIOs: Get Ready to Operate Under Multiple Energy Provisioning Business Models

Data and Analytics for Good

Analysis By: Julian Sun, Fay Fei

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

"Data and analytics (D&A) for good" is a movement in which people and organizations transcend organizational boundaries to use data and data-driven insights for a good cause. This data usage may be within a data sharing, analytics and business intelligence (BI) context or in more sophisticated data science and machine learning use cases, but the purpose is focused on social impact.

Why This Is Important

China is implementing a national data strategy from the 14th five-year plan centered on strengthening the country by nurturing a digital China and a smart society. As the digital economy with AI-generated content as one of the key drivers, the ethnic usage of AI to generate data and analytics content requires more data literacy. As commercial organizations have both the technology and the people needed to improve things for the welfare of society, the public and private sectors are collaborating to construct better cities based on data.

Business Impact

As per a recent Gartner CIO survey, D&A solutions are CIOs' top investment priority in China, but culture and a lack of analytical skills remain barriers, especially for nonprofit organisations and the public sector. The pursuit of social good through data is, in fact, integrated into the aligned outcomes of organizations due to China's unique regulatory framework. In the West, such alignment does not exist. Therefore, data for good in China is not "antagonistic" to business but rather an integral part of what businesses should be doing.

Drivers

- The hype around the AI-generated content market in China brings more potential to healthcare as open source and plays an important role in bringing generative AI capabilities to speed up the patient experience.
- D&A for good initiatives are social responsibility rebranded. Local data and analytics service providers are engaging more with nonprofits and the public sector, and getting more deals for smart city projects. As the Chinese government builds a more centralized and digital system, organizations taking a D&A-for-good approach will get more social impact investment.
- The Chinese government has collaborated with commercial organizations to develop multiple analytics applications, such as Health Code to prevent and combat epidemics. This is reinforcing people's understanding of the power of D&A for good.
- The artificial intelligence (AI) ethics issue gets more attention around tech giants in China, requiring more restricted algorithm governance and regulation to do D&A for good.

Obstacles

- D&A for good is specifically advantageous for organizations that are both contributing the data and using it. To date, such contributions are often considered altruistic, and justifications for participating can be difficult to develop. D&A-for-good initiatives could extend and witness growth well into the future.
- Organizations are seeking equitable solutions that ensure a safe and healthy environment. However, China-based data and analytics vendors lag behind international counterparts in D&A-for-good approaches due to the lack of product strategy enabling such practices.
- The low data literacy of organizations in China will cause less engagement with D&A-for-good initiatives from citizen users.
- D&A-for-good initiatives sponsored by local governments may end up being propaganda products with no usage scenarios that cannot be adopted in the business world.
- The release of the data security law and personal information and the privacy law requires a more secure way for organizations to share D&A for good.

User Recommendations

- Collaborate with international companies and vendors to prototype D&A-for-good strategies as a way to improve employees' data literacy.
- Use analytics based on open data, such as COVID-19-related data or synthetic data, to solve social problems through internal training programs.
- Encourage employees to participate in more community events hosted by organizations that have D&A-for-good projects.
- Pilot data visualization technologies about smart cities to bring more visibility about how data can improve city life.
- Make useful internal data public to solve urban problems while adhering to privacy regulations.
- Promote the usage of and contribute to open-source generative AI technology to facilitate healthcare use cases.

Sample Vendors

Alibaba Cloud; China Unicom; Heywhale; SAS; Tableau Software

Gartner Recommended Reading

Quick Answer: How Can We Start a 'Data, Analytics and AI for Good' Initiative?

Prioritize Data Sharing Investments for Digital Business Success

Modernize Your MDM Program With External Master Data Sharing

Dare to Dream! Give Your Data and Analytics Initiatives a Purposeful Mission to Improve the World

Top Trends in Government for 2022: Data Sharing as a Program

At the Peak

Smart and Sustainable Building

Analysis By: Gavin Tay, Tori Paulman

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

A smart and sustainable building is a facility where multiple functions cooperate to achieve work-life ambiance and broader sustainability outcomes. Such outcomes encompass automation, efficiency, experience, wellness, safety, sustainability and security through the analysis of contextual and real-time information, shared among Internet of Things (IoT), information and communication technology (ICT), and operational technology (OT) systems.

Why This Is Important

Smart and sustainable buildings advance with a heavy reliance on smart technologies although a common data environment is at the core. Building management system (BMS) adoption rates are fairly slow due to its legacy nature. Hardware for HVAC and lighting implemented with new construction has a lifetime of 10 to 20 years. System failure retrofits have heightened with stringent standards of safe management accelerating the importance of experience, well-being, safety and sustainability.

Business Impact

- Increasing people centricity and a growing focus on sustainability will demand not only decarbonization, but also a shift from energy efficiency to incorporating renewable energy.
- Building performance can be optimized and predictive and preventive maintenance can be improved by responding to real-time human preferences based on activities, emotions and reactions.
- Formulating holistic solutions will stretch alignment of cross-functional teams to address work-life ambience and sustainability.

Drivers

- Today, the operating elements of a smart building typically include space, environment and maintenance management, along with wellness, safety, energy management, sustainability and workplace experience. Such rapid evolution of smart buildings means that facilities and real estate professionals will want to leverage the CIO portfolio.
- Energy efficiency such as use of solar panels has long been a key area of investment for smart building technologies. However, incorporating or reselling surplus renewable energy is emerging at an exponential rate.
- As the pent-up delay of new building construction gets underway, demand for a reinvigorated experience particularly in commercial buildings and coworking spaces will rally a surge for an orchestrated AI-augmented infrastructure alongside expertise to bring it to reality.
- The demands and expectations of workers from workplaces are shifting from merely good air, temperature and hygiene to work-life ambience. As a result, a smart building experience requires the exploitation of an ever-growing number of IoT business solutions that are intelligently cohesive.
- IoT and AI have the potential to speed up the implementation of more IT into a common data environment by extending and augmenting existing equipment. Cost savings can be achieved by integrating the sensors with BMS software in older buildings. Sometimes, it is more economical to upgrade rather than adapt to an older system.
- Various nations and organizations have a strong commitment to sustainability, driving the focus of management from pure energy to broader environmental parameters such as water, air quality and waste.

Obstacles

- CIOs assembling smart and sustainable buildings lack a clear vision of the architectural building blocks comprising a common data environment and an understanding of the privacy and data security implications increasingly.
- Delivering total experience is diverse and complex, when managing a multivendor IoT landscape and technology architecture with limited exposure to governing moving parts and the flow of activities in buildings.

- Gartner estimates that by 2028, there will be over four billion intelligently connected IoT devices in commercial smart buildings, making it hard for CIOs to provision, manage, connect and analyze their data.
- Coordinating varied expectations, use cases and budgets from different stakeholders such as facilities management, HR, and CISO (security, privacy and data sovereignty) adds to existing complexity.

User Recommendations

- Broaden corporate priorities in construction and building management by focusing on decarbonization and other sustainability initiatives.
- Address energy inefficiencies by using real-time data from the IoT and IT infrastructure to enable communication between the different BMSs or energy management systems (EMSs) in a building. According to ENERGY STAR, average buildings waste 30% of their energy in lighting, heating and cooling areas that are not occupied.
- Leverage the advantages of IoT to build holistic, engaging experiences while increasing building efficiency and competitiveness. Alleviate the potential business and technical challenges of creating a piecemeal smart building.
- Opt for flexible payment methods, and don't treat such investments as a capital liability. Channel the savings obtained from building efficiencies to the repayment of these solutions or services, making it an operating expense instead (e.g., energy management contracts).

Sample Vendors

Eutech Engineering; General Electric (GE); Honeywell Forge; Intel; Johnson Controls; Schneider Electric; Siemens; Signify; Spacewell; Terminus

Gartner Recommended Reading

Tech CEO Insight: Align the Smart Building Value Communication With the Shift Toward Well-Being and Sustainability

Creating Sustainable and Innovative Smart Buildings Through Data

How Technology and Data Can Be Used to Develop Smart Building Solutions

Emerging Technologies: The Future of Sensing

Heavy-Duty EV Charging

Analysis By: Pedro Pacheco

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Heavy-duty electric vehicle (EV) charging technology is used to efficiently charge heavy-duty electric vehicles, including buses, trucks and electric ships at a 2 megawatt (MW) power or higher. Solutions are designed to enable high levels of operational efficiency by limiting vehicle charging time and maximizing operation time.

Why This Is Important

Regulations across markets such as Europe, China and some U.S. states such as California will boost adoption of electric buses and trucks. For instance, California has mandated the end of internal-combustion truck sales by 2035. Charging equipment designed to deliver the very high voltage necessary to recharge large batteries will be necessary in order to make battery-powered large vehicles practical for long-distance travel.

Business Impact

Heavy-duty vehicle OEMs will struggle to sell electric trucks, buses and ships without a dense network of purpose-made heavy-duty EV chargers, because the passenger car charging network doesn't deliver enough charging speed. The European Automobile Manufacturers' Association (ACEA) has asked the EU to impose specific regulations prompting member states to install at least 11,000 chargers for heavy-duty vehicles until 2025. This clearly defines an urgent necessity for heavy-duty chargers.

Drivers

- Regulation is and will be the major driver for heavy-duty vehicle electrification in land, sea or air. Truck and bus regulation is currently the most advanced from all heavy-duty vehicles. Chinese government incentives resulted in 49% of the buses sold in the world last year being electric. California and some other U.S. states have been approved by federal regulators to enforce a 2035 ban on internal combustion truck sales. In addition, the EU has mandated new heavy-duty road vehicles to, by 2035, reduce its CO2 emissions by 65% in comparison with 2020 values. Electric ships and other heavy-duty vehicles will indirectly benefit from this regulation by having cost-competitive EV charging solutions they can source from heavy-duty road vehicles.

- Given that buses and trucks require a much larger battery than a passenger car, they need higher-power chargers, reaching 2 MW and beyond. These vehicles have a much higher utilization rate, being driven much more than a passenger car, and profitable operations depend on the ability to deliver a short recharge time for these vehicles' batteries.

- Besides the need for a dedicated charging infrastructure, a high number of chargers is also essential. For instance, in Europe, truck stops across main road corridors are frequently packed during nights and weekends. If parking is already an issue, then imagine what this says in terms of the needed number of chargers.

- The shipping sector is also driving heavy-duty EV charging, but to a lesser degree. Even though shipping produces 2.5% of global greenhouse gas emissions, regulation lags well behind road vehicles in supporting zero-emission ships. For instance, the EU has pledged to reduce ship emissions by 80% but only by 2050.

- As road-going EV technology evolves fast, this will make it more economically feasible to adopt it in shipping — especially since electric powertrains have considerably lower operating costs. Currently, this enables a steady pace of adoption in recreational boats and ferries for short sea connections.

Obstacles

- **Slow rollout of specific chargers:** The Megawatt Charging System is still at an early phase of deployment and there aren't yet trucks on the market designed to handle these chargers. Tesla's Semi truck uses their own megacharger design, but so far has only seen a slow roll-out.
- **Regulation:** Only some regions have already developed stringent legislation prompting the progressive phase-out of internal combustion engines in heavy-duty vehicles. This heavily conditions the need for a heavy-duty EV charging network in other parts of the world.
- **Risk aversion:** Even in regions where incentives for EV charger installation are in place, such as the EU, charge point operators fear a long investment payback period. The higher power of these chargers also requires upgrades to the public electricity grid, such as installing substations, which adds to the size of investment. Hence, companies fear investing too early, before there are enough vehicles to justify it.

User Recommendations

Any type of incumbents must:

- Invest in a dedicated heavy-duty charger network only in regions adopting a strong regulatory framework that supports the electrification of this type of vehicle. Without regulation, vehicle adoption will grow slowly, which is a threat to infrastructure profitability.

Vehicle OEMs must:

- Take a chance to invest and build partnerships for developing a heavy-duty charging network. Infrastructure may not grow fast enough to respond to vehicle user needs. Start by investing in roads where infrastructure is needed to unlock major deals with large customers.

Charge point operators must:

- Overcome risk aversion.
- Partner with OEMs, utilities and investors to set up infrastructure.

- Keep track of vehicle sales penetration to judge the right time to deploy infrastructure.
- Implement loyalty models where charging will be an enabler to profit from selling other services and products.

Gartner Recommended Reading

Guide to New Business Models in the Electric Vehicle Ecosystem

Market Guide for Turnkey Electric Vehicle Charging Solutions

Quick Answer: IIJA Presents EV Charging Opportunities and Challenges

Industry Insights: Top 10 Trends Driving the Utility Industry in 2021

Forecast: Electric Vehicle Shipments, Worldwide, 2020-2030

Privacy in China

Analysis By: Bernard Woo, Anson Chen

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

Privacy in China is regulated by the Personal Information Protection Law (PIPL), along with accompanying sector-specific, cross-sector and cross-border data transfer regulations. While similarities with privacy laws such as the EU's General Data Protection Regulation (GDPR) exist, there are distinct requirements and enforcement is guided by multiple regulatory bodies.

Why This Is Important

The PIPL significantly alters the legal and regulatory landscape in China. Previous enforcement had been based primarily on provisions in the cybersecurity law and personal information security standard. The PIPL offers Chinese citizens a much more expansive framework for protecting personal data about them, and includes the potential for powerful financial sanctions: 5% of previous year's annual revenue or 50 million renminbi, whichever is higher.

Business Impact

The compliance risks and potential penalties for violations are real. Business leaders must account for privacy in their market growth strategy, especially in sectors related to national security, such as financial services or multinational operations expanding in China.

While the regulatory framework is similar to principles found in laws in other regions, complex data localization, consent and cross-border transfer requirements must be carefully analyzed and addressed in the privacy strategy.

Drivers

The current regulatory framework follows a path of continued evolution to drive a balance between innovation and societal well-being when processing personal data. Consider the series of laws that have been implemented since 2017:

- 2017 — The Cyber Security Law (CSL) of the People's Republic of China (The National People's Congress of the People's Republic of China) (an English translation is available from Stanford University's DigiChina Project) began establishing requirements around the processing of personal data.
- 2018 — The CSL was supported by the Personal Information Security Specification, also known as, "Privacy Standard" (Secretariat of National Information Security Standardization Technical Committee) and the Guideline for Internet Personal Information Security Protection.
- 2019 — The Multi-Level Protection Scheme (MLPS) 2.0 (Reed Smith), which describes security practices for IT systems, including those that process personal data, went into effect.
- 2020 — The Chinese Civil Code (State Council of the People's Republic of China) was adopted that provided individuals with the right to privacy.

- 2021 — The PIPL (Stanford University' DigiChina Project) went into effect.
- 2022 — Cross-border data transfer (CBDT) regulations were established (see Prepare for the Security Assessment of Outbound Data Transfers From China and Office of the Central Cyberspace Affairs Commission [an English translation is available from Stanford University's DigiChina Project]).
- 2023 — China has indicated a desire to create a new regulator with local branches that would together enforce regulations related to the management of data in the country, adding another set of regulatory bodies to the mix (see announcement from Big Data Administration of Hainan Province).

Regulators have shown a desire to enforce penalties for noncompliance, as witnessed by the $1.2 billion fine issued to the rideshare company DiDi Global.

Obstacles

- The PIPL indicates a heavy reliance on obtaining individual consent for a range of processing activities, with organizations bearing the burden of proof.
- The CBDT regulations dictate strict controls around cross-border data transfers. This creates significant burdens for strategies managing the flow of data in or out of the country. Further, the regulations apply to both consumer and employee personal data.
- The regulatory environment includes IT security frameworks, such as the MLPS 2.0., meaning assessment and certification by locally approved entities is needed. As such, local partnerships are critical in helping organizations understand all applicable requirements (e.g., CBDT), implement correct measures and keep up with changes in a rapidly evolving environment.
- Significant additional investments may be required. Possible new technology investments include IT infrastructure, application architecture and data management solutions. New roles, controls and policies would also be needed.

User Recommendations

- Extend existing corporate privacy practices to incorporate China's regulatory requirements where appropriate and establish new processes when required.
- Discover, map and classify personal data being processed to lay the foundation for gaining control over processing activities and addressing localization requirements.
- Focus on building a privacy user experience (UX) to bring transparency to personal data processing activities, collect and manage user consent plus preferences, and support subject rights requests.
- Establish and document purposes for processing personal data as part of privacy impact assessment (PIA) process; ensure a minimum amount of data is processed for each purpose.
- Implement controls to protect personal data commensurate with that information's sensitivity, such as encryption, data masking/anonymization or access controls (including logging and monitoring).
- Ensure data localization and outbound transfer requirements are addressed within the overall business strategy.

Gartner Recommended Reading

Still a Moving Target — What to Do With the Chinese Data Security Law

State of Privacy — China

Executive Leaders: Top 10 Questions About Digital Business in China, 2022

Security and Risk Management Leaders' Guide to Data Security in China

Digital Twins of Government

Analysis By: Milly Xiang, Bill Finnerty

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

A digital twin of government (DToG) is a virtual representation of government and partner assets, people, and operations to mirror reality and provide real-time analysis, operation automation and scenario-based planning. Key features include a single point for data visualization, access to APIs for issuing commands to things and processes, and the ability to model systems and the built world. A mature DToG is a system of systems that requires strong integration capabilities.

Why This Is Important

It is becoming increasingly important to visualize cross-jurisdiction impacts through a single and collaborative interface. DToG addresses the challenge of establishing common operations across interdependent systems. It enables democratization of insights for public administration, the private sector and citizens. A fully realized future state will:

- Integrate data from multiple sources
- Enable real-time decision making
- Drive scenario planning
- If applicable, add control capabilities

Business Impact

- Short term, piloting digital twins for identified business use cases can help governments exploit their capabilities and impact on operations.
- Medium term, digital twins empower governments with real-time decision-making capabilities for all types of operations centers.
- Longer term, digital twins enable modeling and testing scenarios related to policy, legislation, and infrastructure rollout and changes.
- Over time, digital twins will enable automation of command and control for governments.

Drivers

- **Advances in vendor solutions** — In addition to new vendors entering the market for digital twins of the built world, existing providers are expanding their capabilities. These vendors frequently include low-code integration to IoT datasets; integration with indoor GIS, building information modeling and computer-aided design solutions; and inclusion of AI and machine learning capabilities. These solutions are contributing to cost savings related to preventative maintenance, improved operations through better uptime and real-time decision-making support.
- **Progress on establishing national digital twin programs** — Governments in Australia, China, the U.K. and other countries are establishing national working groups and standards for digital twins of the built world, including those used for government. These programs are further advancing the interoperability of DToGs, an essential component of their use across jurisdictions.
- **The growing application of digital twins to real-world problems** — The number of prominent DToGs being developed to solve real-world problems continues to grow. Examples include Virtual Singapore, New South Wales Spatial Digital Twin, Shanghai's digital twin, the Dutch government's digital twin of The Hague, Helsinki's Kalasatama Digital Twins Project and Boston's digital twin of the city.
- **Future-state drivers** — These will include the use of digital twins, combined with other technologies (such as augmented reality and metaverse), to plan, design and engage stakeholders in building and optimizing physical spaces such as parks or government buildings. The ability to shift a twin used in this phase to one supporting operations will be essential. Inclusion of this type of twin will become a standard part of contracting for design and development of new spaces.

Obstacles

- Foundationally, DToGs are integrated systems that span the silos of government, and silos are an ongoing challenge for governments. Breaking the silos requires coordination on data standards, integration capabilities and, most importantly, governance.
- In many jurisdictions, expectations of DToGs are high. However, due to their technical complexity and the cost, skills and time required, sustaining interest, budget and business unit participation in developing a twin will require focus over multiple administrations.
- CIOs planning for DToGs will need to address fundamental questions of any emerging technology — those related to privacy, ethics and business value. This means that, at first, the question asked is not “Can we do this?” but “Should we do this?”
- The skills to develop digital twins are limited in most markets. Thus, governments will need to compete with other entities for talent.

User Recommendations

- Engage elected officials and program leaders in defining the DToG vision in business terms to maximize understanding and buy-in.
- Use planning exercises (that is, scenario planning) to develop use cases that can demonstrate the “art of the possible” and prioritize investments.
- Establish a guiding principle to protect citizen data by implementing privacy controls and end-to-end encryption.
- Make a digital manifestation of a single aspect, particularly in early stages. The DToG need not be a complete clone of the jurisdiction. For instance, transportation-related digital twins have been created for rail stations in China and for city mobility in Colombia.
- Assess relevant solutions that could support your vision, based on their ability to integrate with existing systems, use of nonproprietary data standards, ability to scale using cloud services and vendor technology roadmaps.

Sample Vendors

AVEVA; Cityzenith; Esri; Eutech Cybernetic; Hexagon; IBM; Idrica; Worldsensing

Gartner Recommended Reading

Market Guide for Technologies Supporting a Digital Twin of an Organization

Emerging Tech: Tech Innovators for Digital Twins — ET/OT Providers

Emerging Tech: Tool — Digital Twin Business Value Calculator

City Asset Management

Analysis By: Milly Xiang

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

City asset management refers to the use of combined digital technologies — such as Internet of Things (IoT), computer vision, 3D mapping, augmented reality (AR) and virtual reality (VR) — to visualize and monitor fixed and mobile assets, both above and under the ground. The assets include infrastructures like maintenance hole covers, underground tunnels and pipes, and equipment used for city initiatives such as snow clearing, street cleaning or landscaping.

Why This Is Important

City asset management enhances security, prevents theft and tracks usage and location of these assets to increase utilization. Data collected from these assets supports collaboration across various stakeholders for the purpose of:

- Construction, rebuilding and maintenance to avoid costly damage and accidents
- Asset utilization, location and work process
- Alignment and coordination across owners of these assets
- Health and safety issues of workers or the public

Business Impact

A high degree of visibility of complex and distributed city assets can:

- Improve overall urban planning and decision making
- Save costs around redundant equipment
- Increase productivity with on-demand, event-based maintenance and repair
- Reduce safety incidents through remote monitoring and predictive maintenance
- Improve citizen satisfaction by reducing service delays and damages, road closures and other incidents

Drivers

- The Chinese government work report in 2022 and the 14th Five-Year Plans by various cities emphasize the effort to accelerate city asset management to further improve the quality of city administration and citizens' living standards.
- The need for spatial data (both above and underground) is a key element in the design of smart cities. In particular, high-resolution, 3D data frameworks are essential components of cities' digital twin roadmaps. Hence, many initiatives to improve knowledge of location and condition of city assets and infrastructure are already underway, including related policies, collaborative working across public and private sectors, and innovation on enabling technologies.
- The growing recognition of the benefits of accurate location, utilization and status of the assets, as well as data sharing across different owners and contractors, are accelerating momentum to create a digital twin at the municipal level.
- The implication of effective city asset management around greater safety, resilience and disaster response, sustainability and well-being are driving more actions among both public and private sectors involved in city assets and infrastructure management.
- The growing number of startups focused on technological innovation makes cost-efficient, safe and rapid capture and processing of data more feasible, to create accurate monitoring and 3D maps of the underground infrastructure and assets. These include underground detection, reality capture, augmented reality and software that can extract 3D underground information from consumer digital photos and videos.

Obstacles

- The complexity and scope of assets above and under the ground, and potential investment required, prevent most cities from making such work a priority.
- For underground assets, current investment mostly focuses on building physical infrastructures such as underground pipe corridors. The adoption of digital technologies to monitor and manage these infrastructure and assets held in them is still in the emerging stage.
- The stakeholders of various city infrastructure and assets still focus on the value of finished assets, rather than the entire life cycle of an infrastructure asset.
- Integration of city asset data with other city data and services is challenging on account of different data formats, standards, interfaces and platforms.
- Data sharing and coordination across multiple stakeholders are complicated by lack of documentation of the exact information on assets; varying data formats and standards; and multiple versions of information captured for different projects.

User Recommendations

- Focus on cross-sector collaboration to combine multiple data sources, such as existing GIS, building information modeling (BIM) and IoT data, to create an initial, virtual, up-to-date map of the city asset.
- Build and optimize a management platform that combines data collection, verification and visualization based on roles in the organization and other stakeholders.
- Develop a conceptual action framework to improve asset data interoperability, governance and exchange across multiple stakeholders.
- Joint research and co-innovate with urban ecosystem partners — into detection and modeling, emerging image capturing and surveying techniques, augmented reality, high-accuracy positioning and digital twins — to digitally map, document and interact with the breadth of city assets above and under the ground.

Sample Vendors

China Mobile IoT; H3C; Moxa; Nanjing Woxu Wireless; Shenzhen Launch Digital Technology; Shenzhen Yiyuntian Electronics; Tencent Cloud; Unicom Digital Technology Co.

Gartner Recommended Reading

Technology Opportunity Prism: IoT in Smart Cities

Market Guide for Enterprise Asset Management Software

Infographic: Artificial Intelligence Use-Case Prism for Smart Cities

Digital Twin of a Citizen

Analysis By: Milly Xiang, Alfonso Velosa

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

A digital twin of a citizen (DToC) is a technology-enabled proxy that mirrors the state of a person. National, state and local governments use DToC to support citizen services such as health or safety management. Its elements are the model, data, a unique one-to-one association and the ability to monitor it. It integrates data into the DToC from siloed sources such as health records, credit scores, phone logs, criminal records, customer 360 records, and sensors such as cameras.

Why This Is Important

Governments are developing DToCs to address health, safety, environment, travel and contextualized social media impacts on society. The spectrum of the complexity of the models and tools can help governments make better decisions for monitoring and supporting constituents, such as patients, prisoners, passengers or the elderly. The Chinese government has been building and improving its social credit scoring methodology. Aggregated DToCs can help map broad patterns and drive resource allocation.

Business Impact

Governments can use DToC to better orchestrate personalized services and manage crises, for example, modulate climate crisis against human loss. Aggregated data can help citizens expedite government services, especially in smart city environments. Citizens or governments can drive DToC-based crowdsourcing analysis that mirrors reality to assess government services in real time. Governments can integrate services into systems such as passport control, social credit system and shopper tracking solutions.

Drivers

- The Chinese government is gradually improving and optimizing regulatory and organizational foundations. Examples include Data Security Law of the People's Republic of China, Personal Information Protection Law of the People's Republic of China, and the upcoming National Data Bureau, to promote secure and controllable data exchange across public and private sectors.
- There is an increasing proliferation of both structured and close-to-structured data on creating digital citizen journey maps.
- Increased integration of government, financial and commercial systems, and interest in creating citizen 360 models are driving pilots of DToC in multiple areas.
- Citizens' interest in improved health and safety systems is increasing. And the need for proactive, real-time, personalized government services customized to citizens (for example, for emergency medical services) and longer-term, more complex solutions that serve elderly patients or inmates is driving investment from a broad range of government organizations. Some examples include solutions to monitor elderly patients using IoT-enabled trackers, smart camera monitoring systems that track a specific police officer, or inmate tracking solutions under home arrest.
- The flexibility of digital twin models from simple to complex models, and the ability to integrate data from siloed services, enable government agencies to build out citizen services to serve individuals as well as the public at large.

Obstacles

- Concerns around privacy and government access to citizen data are leading to citizen concerns and pushback.
- High costs for DToC projects inhibit scaled deployment, especially with a lack of commensurate benefits to citizens or government agencies.
- Conflicting government agencies' objectives, political infighting on data rights, and incompatible regulation on the use of citizen data and on how to respect rights to privacy.
- Incompatible systems across government, commercial and healthcare silos, driving high costs for data governance, integration and analytics, affecting incident handling efficiency and limiting communication.
- Lack of skills to drive the use of the citizen twin and knowledge on possible use cases in government agencies slow down adoption.
- There is an overall low awareness of DToC by government organizations and urban partners, in terms of how a DToC approach can be built and used in an effective manner.

User Recommendations

- Establish clear benefits for the government agency(ies) to justify not just the cost of developing the DToC, but also of changing the culture and adapting processes to the new data.
- Establish clear benefits to citizens such as shortening passport control lines, simplifying access to medical care, or aligning payments from citizens for use of a toll road.
- Test and validate acceptance by the public by communicating the DToC offering and its benefits.
- Build robust privacy and digital ethics policies that clarify what data is collected, who has access to it, how it is protected, and citizen remediation processes.
- Test IoT sensor and analytics capability to ensure accuracy and validity for the physical part of a DToC.
- Invest in integration skills to connect into a heterogeneous set of applications and data sources and critical incident handling.
- Build data exchanges to protect data, while enhancing the granularity of citizen data used to drive government services.

Sample Vendors

Alibaba Cloud; Apple; Google; Taiji Computer; Tencent; Vantiq; ZKBRAIN

Gartner Recommended Reading

Market Insights: Unique Regional Dynamics Require Tailored Strategies for Smart Cities in Asia

Life Cycle Management of Software-Defined Vehicles: Step 3 — Vehicle Digital Twin 2.0

Quick Answer: Privacy Basics for a Digital Twin of a Customer

Emerging Tech: Tech Innovators for Digital Twins — Digital Business Units

Sliding into the Trough

Data Governance

Analysis By: Tong Zhang, Julian Sun

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Adolescent

Definition:

Data governance is the specification of decision rights and an accountability framework to ensure the appropriate behavior in the valuation, creation, consumption and control of data and analytics. It encompasses the people, processes and technologies required to manage, protect and utilize data assets.

Why This Is Important

Data governance defines the guardrail of data assets. It provides a holistic approach to collecting, managing, securing and storing data and ensures value generated from data through the proper process with the right people using relevant technologies. The rapid business-value-focused D&A initiatives from Chinese organizations have left data governance risks unaddressed, which impedes the scale-up of D&A and organizational data-driven strategy.

Business Impact

- The accuracy, timeliness and reliability of data affect the quality of business decision making and data-driven insights. Data governance helps organizations to avoid the costs associated with poor data quality, such as rework, data cleaning and data integration.
- Effective data governance builds trust and confidence among stakeholders, including customers, investors, and employees, that the organization is managing data responsibly.
- Data is defined as one production factor in China. The economy of data requires a good governance guardrail and framework to be applied to all organizations.

Drivers

- Compliance with regulations such as China Cybersecurity Law (CSL), Data Security Law (DSL), Personal Information Protection Law (PIPL) are key drivers for implementing data governance to ensure that data is managed, secured, audited and utilized properly.
- As a new form of product, data becomes a key differentiator and could provide a competitive edge for businesses. Extracting business value from data relies on good data quality and various data elements enabled by data governance.
- Businesses rely on data governance to avoid risks such as data breaches, data loss, unauthorized access and the costs associated with insufficient management of data.

Obstacles

- **Inability to persuade business partners that data is a business concern, not an IT concern.** While business partners conceptually agree on the importance of data quality, consistency and access, they push back on taking direct ownership of data decisions, perceiving that data is an "IT thing."
- **Difficulty to define and adopt consistent data governance processes and policies.** Without a formal governing body with both business and IT representation and a targeted scope, governance processes will fail to be adopted and benefit will be diluted. The comparatively unstreamlined and vague business processes in China have amplified this problem.
- **Failure to come to consensus on common enterprise data definitions.** Business unit heads tend to view their data needs as unique rather than consistent with other areas of the enterprise.
- **Inconsistent approach to data across projects.** An inconsistent approach across the enterprise puts project solution outputs at risk of being at odds with each other and fails to achieve scalability, slowing down projects as tasks and documentation are reinvented for each project. The lack of mature data governance vendors has amplified this problem.
- **Difficulty to define and sustain a path toward a target state of data competency.** Achieving data quality, accuracy and consistency is a vast and amorphous objective. Organizations struggle to identify a realistic target state of data competency and the interim milestones to reach in the near term and midterm.

- **Uncertainty of regulation changes makes data governance more compliance-driven rather than value-driven.** Data governance is expected to deliver value to business rather than to avoid risk. Business needs to manage risk to generate value.

User Recommendations

- **Clearly scope the data governance mandate and objectives.** Clarity of purpose will provide the focus to apply scarce resources to the most important governance activities.
- **Apply varying degrees of governance depending on the data asset.** Prioritize the highest level of rigor on the data assets with the highest business value and broadest enterprise use.
- **Involve the business in data stewardship roles and tasks.** Data is a business asset and needs to be managed as such by business owners. Ensure business representation on stewardship boards.
- **Take an opportunistic approach to data standardization.** Pursue opportunities for data standardization and integration that are highlighted by events in the business environment, such as a merger or new senior executive, that would trigger new information requirements and needs.
- **Prioritize data quality improvement based on the data's quality gap relative to its importance to the organization.** Highlight data quality concerns from multiple user perspectives and in varying contexts to ensure the right data is targeted for quality improvement.
- **Study China's National Data Bureau regulation and China data policy updates.** Exploring new opportunities is key to success in data governance. The National Data Bureau will set the direction of new use cases of data.

Sample Vendors

Alibaba; BONC; Datablau; ESENSOFT; Huawei; JKStack

Gartner Recommended Reading

Playbook: Building a Modern Data Governance Program

Distilling Data Governance Essentials for FP&A Leaders

Market Guide for Data and Analytics Governance Platforms

Data and Analytics Governance as a Business Capability: A Gartner Trend Insight Report

3 Ways to Promote Your Data Agenda at the Center of the Chinese Digital Economy

Intelligent Street Pole

Analysis By: Bettina Tratz-Ryan

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

An intelligent street pole is an asset that hosts a variety of different IoT and networking devices, cameras, monitors and displays. It is controlled and monitored from a single operator, and possibly enables EV charging, interactive lighting, air quality monitoring, parking management and crowd management. It can provide the backbone for a citywide Wi-Fi or 5G network that can enable computing and communications for intelligent street and district services.

Why This Is Important

Intelligent street poles are an evolution of smart street lighting, which has moved rapidly into mainstream adoption. Compared with light posts, street poles host a variety of different sensors and technologies, and enable a concerted aggregation of location-based data. The maturity of context-based analytics will accelerate around parking options, asset management in the vicinity of smart buildings and real estate, and retail locations in downtown areas.

Business Impact

Intelligent street poles will become valuable real estate, as their location and ability to connect many sensors can avoid multiple installations and provide cost-efficiencies. In addition to street furniture, sustainability is becoming an additional value added contribution for street poles, as they will also host air quality monitors or manage the lighting intensity of the luminaires. It is expected that street poles may include charging stations, parking meters and intelligent edge systems.

Drivers

- Intelligent street poles will become the center of monitoring and communications platforms while hosting intelligent edge computing capabilities for intelligent streets or districts. User experiences in tourism and public safety will highly benefit from situational awareness mapped to location — and user-centric data. Cities like Amsterdam and Los Angeles are using the availability of data analytics to manage lighting, music, public messaging and other features directly mapped to crowd or vehicular movement.
- Street poles, as well as devices mounted on the poles, are owned by public works, utilities or private-sector stakeholders and, therefore, serve a variety of different business purposes. These include urban planning decisions, services for micromobility, support for last-mile logistics and development of new business districts. The poles can serve as a valuable urban real estate for a 5G base station, EV parking and concierge services, and private-sector curb pricing for property insurance or retail per square foot of curb space.
- Business momentum will be triggered by the gains from managing the data complexity that will drive ROI and future-proof implementation in “greenfield” locations and districts.
- Smart street poles will be deployed in parking garages or as part of smart real estate development from the private sector. Urban leaders could apply them to revitalize locations or create innovation hubs by offering data from street poles to ecosystem partners, with new AI and video analytics technology.

Obstacles

- Obstacles to ecosystem development include the complexity of ownership and the varying expectations of ROI benefits. Utilities, SP and real estate developers emerge as deployment stakeholders.
- Issues around management of assets mounted on poles, together with maintenance, data orchestration and cybersecurity, need to be addressed to enable scalability and drive adoption.
- Privacy concerns will arise based on location analytics of the smart pole that can connect a variety of different datasets from additional sensors, leading to personalization of user behavior. As an example, Google Sidewalk Labs in Toronto was shut down because citizens were not comfortable with data collection on a square footage basis.
- Issues in data sharing of different types of sensor data at the edge will lead to slow adoption of ecosystems business models

User Recommendations

- Classify sensor data and insights gained from the street pole through analytics to generate value for smart city, smart street or district deployments. Develop scenarios to calculate the connectivity, computing and powering requirements for multiple IoT sensors on the pole. This is critical, as cyber-physical systems and mesh technologies may define and execute on the linked data analytics or data graphing off the post.
- Manage upfront how you will mitigate privacy concerns as use cases build. For example, inform others that initial lampposts with sensors and CCTV cameras will turn into intelligent street poles.
- Enforce digital security at the individual asset level of the pole, as well as at the edge gateway and transmission to the core of the street pole ecosystem. With the increasing mesh of interactions and value generation, access is increasing for potential digital intrusions, as well as privacy violations.
- Determine location, connectivity and compute power to gain ROI and value streams.

Sample Vendors

Acuity Brands; CIMCON Lighting; Fluentgrid; Signify

Gartner Recommended Reading

Technology Opportunity Prism: IoT in Smart Cities

Technology Assessment: Urban Mobility, 2030

Interjurisdictional Government Services

Analysis By: Milly Xiang

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Emerging

Definition:

Interjurisdictional government services aim to streamline government administration and services. They transform traditionally, geographically or functionally bound government services to a model that effectively meets the needs of people and enterprises to access services in a one-stop-shop manner or in places outside their home jurisdiction. A call for strengthened data sharing and mutual recognition of digital identity and universal rules and standards underlines this transformation.

Why This Is Important

Creating interjurisdictional government services is an important way to transform people-centric and service-oriented governments. It's an effective way to unblock functional and geographical border and jurisdiction silos of government services to further enhance governmental service efficiency and experience by minimizing the time and labor cost of enterprise and individual.

Business Impact

- Drive standardization of the government service processes, related rules and regulations.
- Encourage data sharing across different government functions and geographies to maximize data value.
- Enhance public service capacity, overall satisfaction, and coordinated citywide and regional development.

- Enable greater public and private service and urban ecosystem orchestration.
- Facilitate people and business roaming across geographies to stimulate the vitality of the economy.

Drivers

- The development of cities, urban agglomerations and regional economies lead to an ever-frequent population flow from rural to urban areas and between cities. Living and working in nondomicile places have become the norm. Accessing governmental public services without geographical boundaries leads to the grassroots needs of unified online government services and nationwide planning of digital government.
- In September 2020, the general office of China's State Council issued the guiding opinions on accelerating the promotion of "interjurisdictional government services," defined the list of high-demand government services and set the timeline of realizing these services subsequently by 2020, 2021 and after.
- Government service platforms covering more than three levels of provincial, city, country and even township and village services have continued to expand. Online government services have gradually become a reality, laying the foundation for government services across "geographical barriers."
- Experiences and practices in some urban agglomerates as a result of regional economic integration and coordinated development (e.g., Jing-Jin-Ji, Yangtze River Delta, Greater Bay Area) give guidance and lessons learned to other regions.
- The accelerated release of data-related regulations and upcoming governmental reorganization to form the National Data Bureau provide a regulatory and organizational foundation for monetizing data assets for improved governmental services that generally align well with private industry best practices.
- The increasing maturity of digital technologies, such as omnichannel, superapps, big data, AI and biometric, drives governments at all levels to exploit new service models in government service and city administration.

Obstacles

- Unbalanced geographical development of digital government leads to uneven orchestration of government services across municipal and provincial borders.
- Data sharing across jurisdictions still faces many challenges including, but not limited to, inconsistent data standards, data quality and data trust. Inconsistent business processes also lead to difficulty in cross-jurisdiction collaboration.
- The experiences related to channel shifts from offline to online services are inconsistent. The design of digital service channels is too complex for most users, leading to low usage rate.
- Laws and regulations still need to be enhanced and specified around data governance, protection of national security, commercial confidentiality, and privacy, as well as avoidance of misuse and disclosure.
- Many governments are still behind on investments in identity proofing, fraud detection and other advanced capabilities necessary to foster trust and adoption among citizens.

User Recommendations

- Enhance cross-jurisdiction data sharing by setting up effective data-sharing mechanisms, specifying data demand and supply, regulating data usage and dispute resolution, and building supervision and assessment measures.
- Standardize procedures and guidelines across provinces by unifying business processes and standards and prioritizing the most required services to accelerate service efficiency and experience.
- Accelerate migration to digital channels with improved experience by designing digital channels as part of a broader ecosystem instead of treating them as silos and monitoring their effectiveness via usage, experience and operational metrics.
- Drive digital identity adoption by facilitating and regulating the digital identity ecosystem and raise trust among citizens by addressing concerns over privacy, misuse of personal identity data, fraud, and more.

Sample Vendors

BONC; CS&S; DT Dream; Hangzhou Bosheng Technology; Huawei; Inspur; Linewell Software; Quanzhi Technology (Hangzhou); Taiji

Gartner Recommended Reading

3 Steps to Effectively Manage Cross-Jurisdictional Risks

Predicts 2023: Chief Data and Analytics Officers Need to Create Value and Make an Impact Now

Build an Identity-First Security Approach to Empower Digital Business in China

Urban Waste Management

Analysis By: Milly Xiang

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Adolescent

Definition:

Urban waste management refers to the collection, transportation, disposal and recycling of municipal solid waste, hazardous waste and wastewater. It encompasses the management of all processes and resources for proper handling of waste materials, to comply with health codes and environmental regulations, as well as behavioral changes. It's either managed by government entities or outsourced to a third-party waste management company.

Why This Is Important

Urban waste management is a fundamental pillar to achieving zero-waste cities, a goal announced by the Chinese government in 2018. Effective waste management empowers cities to battle ever-growing volumes of municipal waste as a result of large-scale urbanization and industrial growth. It poses a great impact on the overall citizen experience, health and environmental sustainability. When properly facilitated, waste can be changed from a problem to a resource, while reducing pollution.

Business Impact

Effective urban waste management allows:

- City officials to optimize their decisions on regulations, infrastructure and cross-stakeholder collaboration, to achieve sustainability goals.

- Waste collection companies to increase efficiency and productivity, and reduce operational costs and carbon emissions from collection and transport.

- Waste recycling companies gain a competitive advantage by proactively adopting technical solutions to enhance classification and recycling efficiency and accuracy.

Drivers

- Advances in waste management are driven by tightening environmental regulations and targets, and the growing importance that citizens attach to sustainability, health, experience and equality. Food waste in cities is driving attention to the inequality in food supply and poverty. Plastic waste generates a pollution crisis in waterways and landfills, shifting the perspective from a public-sector mission to a social predicament.

- Governments have enacted a series of policies and supporting measures around waste reduction, waste separation and waste utilization via energy recovery, aimed to facilitate a shift in focus from waste disposal to waste management. This is to counteract critical waste disposal situations (constraints of land availability as well as associated environmental, health and safety issues) as a result of the predominant reliance on landfill sites.

- Cities continue to push boundaries of what can be done with waste, from recycling network innovation to sensor technologies and smart sorting processes, where digital technology plays an important role in reshaping how urban waste is collected, delivered and recycled.

- New technologies and business models are emerging to modernize the entire waste management process. For example, NarrowBand-Internet of Things (NB-IoT) powered smart trash bins to automate and optimize when and how waste is to be collected, machine vision and search intelligence to observe illegal landfills and optical sorting machines that use sensors to separate composable and other recyclable material.

- As a country that is at the start of its journey in extending its waste management strategy, China is in a good position to draw on the waste management experiences of other economies and assess the opportunities for transference to support its development of zero-waste cities.

- The waste-to-energy model is being increasingly evaluated and trialed by the government as a part of the clean energy initiative along with partners from the private sector.

Obstacles

- The achievement of waste management objectives requires joint efforts from the government, businesses and citizens. But there is a gap between collective responsibility and individual responsibility, as individual organizations deprioritize it over other sustainability initiatives.
- Progress is slowed down due to the lack of a comprehensive and integrated waste management system across local industries and communities, funding for technology investment, knowledge about cost-effective waste management options, and education to cultivate less-waste-generating habits.
- Lack of well-accepted waste classification standards — such as food and recyclable wastes, and waste for energy — leads to varying data collection and reporting methods, making statistics unreliable in quality and comparability.
- Adoption of digital technologies across government and private sectors is inhibited by low digital literacy across the workforce, concerns about business process change and uncertainty on return on investment.

User Recommendations

To incorporate smart technologies to enhance the efficiency and productivity of urban waste management, both public and private sector CIOs need to:

- Observe the changes in policies and measures and invest in technologies that can facilitate the reduction of waste generation, and improve waste recycling and waste to energy.
- Prioritize technology investment on use cases that can generate immediate results in cost reduction, work efficiency and sustainability.
- Evaluate emerging technologies' maturity and cost structure such as pneumatic systems, waste collection robots and autonomous driving waste collection trucks, and technologies to manage specific waste such as plastics, batteries and e-waste, to gradually upgrade waste management in cities.

- Use and analyze data across the waste management life cycle to optimize cross-stakeholder collaboration and infrastructure optimization.

Sample Vendors

ALBA Group; BangBiTuo; Ecube Labs; H3C Technologies; Huawei; Little Yellow Dog Environmental Protection Technology; Tuya Smart; Winmate

Gartner Recommended Reading

Strategies to Reduce Waste and Enhance Circular Supply Chain

Reduce Packaging Sustainability Costs and Risks by Focusing on Waste

Technology Opportunity Prism: IoT in Smart Cities

5G for China

Analysis By: Peter Liu, Sylvain Fabre

Benefit Rating: High

Market Penetration: More than 50% of target audience

Maturity: Mature mainstream

Definition:

5G is the fifth-generation cellular technology standard by the 3rd Generation Partnership Project (3GPP). The standard targets maximum downlink and uplink throughputs of 20 Gbps and 10 Gbps, respectively. Latency is as low as 4 milliseconds in a mobile scenario and can be as low as 1 millisecond in ultrareliable low-latency communication scenarios, down to centimeter-level location accuracy indoors, and massive IoT scalability. New system architecture includes core slicing and wireless edge.

Why This Is Important

5G has been positioned as a national priority of the digital transformation and connectivity of the economy. It is a critical enabler for the booming digital economy together with big data, AI and cloud computing. 5G will also unlock new enterprise services that have stricter connectivity and computing requirements, such as AR/VR, metaverse, smart cities, autonomous driving, Internet of Things (IoT) and smart manufacturing.

Business Impact

5G has the following impacts on enterprises:

- It brings up to 10 Gbps of capacity, higher quality and more secure mobile connectivity options for enterprise networking.
- The introduction of network slicing and edge computing allows customized networks that map to an organization's IT needs.
- With the introduction of private mobile networks (PMNs), enterprises can have their own 5G setup on-site, which leads to performance, security as well as bandwidth economics.
- 5G enables other emerging technologies, such as AI/ML, metaverse, robotics and IoT, to further drive enterprise digital transformation.

Drivers

- China is ramping up plans to construct new digital infrastructure across the country — including 5G networks, AI and IoT. These drive investment in and deployment of 5G.
- 5G offers fiberlike bandwidth and latency capabilities, but with significantly shorter deployment time. With this advantage, it can be positioned as a comparable alternative to fiber for the enterprise data network.
- 5G features, such as network slicing and service-based architecture, allow networks to be purpose-built for use cases (e.g., ultralow latency and security) and be more responsive to the application and IT environments they support. These networks can potentially work with existing SD-WAN solutions or overlay fixed networks.
- There is a growing interest in private mobile networks across multiple industries. 5G is expected to be a potential connectivity option to support future applications such as robotics and mixed reality.
- With the government's policy support, Chinese enterprise CIOs are showing great interest in 5G and proactively collaborating with communications service providers (CSPs) to develop 5G services. This drives innovation and accelerates adoption. In the 2023 Gartner CIO and Technology Executive Survey, 34% of respondents said their organization already adopted or is going to adopt 5G in the next year.
- Fast shipment and penetration of 5G devices is another driver for 5G network rollout.

Obstacles

- Alternative connectivity options such as Wi-Fi and fiber continuously challenge the necessity of 5G adoption in indoors enterprise networks.
- Costs, complexity, lack of skills and knowledge, and security are major concerns for enterprise CIOs when considering 5G technology, especially for enterprises that want to build their own private 5G networks. Current private 5G networks normally are deployed in a silo mode to support niche applications, which hardly justifies the investment.
- The majority of 5G vertical use cases are still in the conceptual and developmental stage. These use cases are mainly driven by the network vendors and CSPs. While 5G will enable various industry applications, the real value to the end users remains unclear.
- The 5G-related capabilities and standards are still evolving. Major enterprise innovation opportunities are based on 3GPP R16 and R17, which are not largely available in today's 5G deployment.

User Recommendations

- Plan for 5G adoption by considering the match between the 5G connectivity service and use-case requirements. Cut through the "5G washing," and set realistic expectations by understanding the multilevel technology dependencies that impact 5G adoption.
- Engage with CSPs to understand the different offers, deployment specifics and how these services integrate with your existing system.
- Leverage 5G to offer new applications such as AR/VR on mobile devices in the mass market to enhance your customer experience and brand advantage.
- Validate expected network performance by making sure that the underlying CSPs provide the coverage data for branch locations, frequencies used and expected throughput.

Sample Vendors

Baicells; Comba Telecom Systems Holdings; Ericsson; FiberHome Telecommunication Technologies; Huawei; Nokia; Qualcomm Technologies; Samsung Electronics; ZTE

Gartner Recommended Reading

Emerging Tech: 5G mmWave at a Crossroads

Magic Quadrant for 5G Network Infrastructure for Communications Service Providers

Communications Industry: 2023 Top Market Trends for CSP Tech Suppliers

Market Guide for 4G and 5G Private Mobile Networks

Quick Answer: What Vendor Product Leaders Need to Know About MWC Barcelona 2023

Water Management Analytics

Analysis By: Bettina Tratz-Ryan

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

Water management analytics are divided into two parts. First is fresh water monitoring for hydrological management, including rainfall, groundwater monitoring, quality review, supply and demand management. The second is waste-water treatment, including quality review and water-loss analysis.

Why This Is Important

Water management requires a differentiated set of technology and service skills. These technologies enable effective water quality, quantity and distribution management, including assessment of risks. As fresh-water resources become increasingly scarce, enhanced water management will increase in importance. Water management data will require more solution capabilities related to an entire management cycle that includes operations, user billing and monitoring, and forecasting of demand and quality.

Business Impact

Consolidating data points to manage and control water issues — from regulation to reuse and recycling — provides water suppliers and municipalities with the ability to achieve cost-effective potable water quality. It improves the interface between asset tools for pumping stations, meters and monitors for better customer services, with fewer water-supply failures and better water quality. Partnerships with IT and water operations have to be built to connect data and information sources.

Drivers

- Residential water needs will compete with business needs, and analytics will be needed to resolve them. South Africa and the state of California are examples for this competition, where water shortage and erratic natural rain are leading to water rationing of society.
- Artificial intelligence (AI) is being used to address infrastructure resilience issues. Adoption is accelerating as emergency response around water crises in drought and flooding, relative to shifts in weather patterns, has captured the attention of local governments and utilities from a risk perspective.
- Water-quality issues triggered by agriculture fertilization are driving up water prices in cities by 50% year over year in countries like Germany or from agricultural pollution. That is accelerating the deployment of new water management solutions and increasing the time to deliver water to customers.
- Climate change priorities are shifting toward water sustainability, capturing the attention of industry players. Government initiatives and the developments in pricing of water will also drive water management — once meters are installed to monitor true consumption.
- Water management is a growing application area for industry and business uses, including touristic sites like beaches and lakes. The recurring red tides in coastal areas in Florida is part of the water temperatures rising, together with pollution that will cause harm to people and livestock.
- Water management offers insights into disaster recovery for water-related issues in manufacturing operations.
- Cities are applying Internet of Things sensors across wastewater infrastructure to measure drug and pharma content and pollution, and provide an epidemiology assessment through the wastewater streams.

Obstacles

- The position of the profile has moved in 2023 in the Hype Cycle because water management has developed more complex use cases.
- While local utility and freshwater supply is experiencing more water intelligence, shortage of climate-related resources and natural disruption are not priced in the supply, thus artificially keeping the delivery cost low.

User Recommendations

- Evaluate the implementation of data management and analytics for water infrastructure and quality. Users (industries and commercial) and suppliers (municipalities) must report, or comply with, tightening wastewater regulations, while improving efficiency and reducing loss and waste-disposal costs.
- Implement security standards in the water management process, the physical infrastructure and the privacy policy on consumer data. For municipal water utilities or sewage plants, water management dashboards will assist in providing real-time data on water quality.
- Develop an adaptive and flexible water management strategy, integrating the legacy of IT and operational technology. IT professionals in utility and municipal contexts can develop strategy based on intelligent information received from environmental sensor and satellite networks, smart water meters and deep computing, and analytics engines.

Sample Vendors

ABB; ADASA Sistemas; Arcadis Gen; Atos; EcoExam; KISTERS; Schneider Electric; SUEZ

Gartner Recommended Reading

Quick Answer: How to Meet a Net Positive Water Commitment

Environment Monitoring and Management

Analysis By: Milly Xiang

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Environment monitoring and management uses new technologies such as IoT, connectivity, big data, machine learning and analytics, to observe the environment (air, water and soil quality, and noise), characterize its quality, and establish environmental parameters. It enables governments and urban ecosystems to measure, view, correlate and analyze data in real time, and set thresholds for critical measurements, to support real-time, science-based and more conscious environmental decisions.

Why This Is Important

Effective environment monitoring and management is crucial to manage and minimize the impact human beings and industrial activities have on the environment. It's essential to ensure compliance, mitigate risks of harmful effects on the natural environment and protect the health of human beings. It supports more precise, data-driven decision making around environmental policies and measures, as well as corrections and advanced changes to systems, such as traffic management to reduce car pollution.

Business Impact

The impacts of environment monitoring and management lie in its ability to track changes in environmental metrics and transform data into insights. It helps governments, municipalities, private and nonprofit organizations to:

- Mitigate drastic damage, assess causes and impacts, and make decisions on interventions, policies and communications.
- Identify and eliminate pollution sources and their impacts on air, natural resources and human health, to support actions on sustainable development.

Drivers

- The Chinese government set aggressive sustainability goals, releasing laws and regulations to define legal requirements. Environment monitoring and improving awareness of the latest dynamics will support policy development and tracking of progress toward the target.
- Most cities in China include sustainability targets as their smart city KPIs, driving initiatives toward greener cities. Cities are in great need of powerful tools to measure the environmental impacts of activities from residential, vehicular, commercial, industrial and other sources. They need data to act on industries and businesses that violate compliance standards.
- Government regulations and measures are forcing local industries to make sustainability commitments to ensure regulatory compliance, and adopt technology for critical insights to pivot to more energy-efficient practices and improve their reputation.
- Technology advances make environment monitoring possible by offering higher levels of sensing accuracy at a lower cost. Data analytics and AI techniques allow cities and businesses to apply real-time analysis, document daily and seasonal changes or identify areas requiring immediate attention, and practice prediction and simulation to support decisions around environmental issues.
- The deployment of smart street poles (thanks to their capillarity, connectivity and electrification) makes them a strategic infrastructure for smart cities to host various environmental sensors and devices to meet the densification requirements for microlevel monitoring.
- Consumer devices recording environmental pollution or noise levels — and pushing into the cloud to a citizen entrepreneurial application — are proliferating, keeping the government accountable.
- The evolution of low earth orbit (LEO) satellites that enable increasingly accurate remote sensing while covering vast geographical distances is starting to viably complement, and in some cases substitute, ground-based sensing solutions.

Obstacles

- Current environment monitoring is dependent on government-based stations, usually sparsely distributed. Thus, the data from these stations cannot provide microlevel and standardized environmental information for assessments.
- The high cost of accurately measuring the environmental data at the microlevel often limits the number of deployments, resulting in gaps in coverage.
- Sensors for environment monitoring have lower accuracy compared with regulatory-grade instruments and are easily affected by environmental parameters such as temperature and relative humidity. They also require regular calibration and maintenance.
- While big data has been used for environmental management planning and actions, there are still gaps around better environmental indicators, measurement methodologies, data management and reporting, adaptive management, and enforcement.
- Both governments and industries face pressure to commit to pollution and emissions control while pursuing robust economic/business growth.

User Recommendations

- Adopt sustainable urban planning standards and practices to improve efficiency and minimize environmental impact, as well as support the creation of a resilient community through regulation implementation and cultural changes.
- Design architecture, site topology and measurement parameters for environmental quality management, focusing on baseline data collection and generating trends, then improving accuracy and precision.
- Leverage the latest sensing and monitoring technologies, and data generated, combined with crowdsourced data collected through consumer devices, for holistic environmental analytics. Use these analytics to assess the effectiveness of policies and measures, so immediate and long-term actions around adjustment and enforcement can be adopted.
- Enable data sharing with industries and the public to empower them with real-time information to arrange their daily activities.

Sample Vendors

Aeroqual; Airthings; HORIBA; IBM; Libelium Distributed Communications; Marston Holdings; OwlSmart; RocKontrol; UNICOM Digital Technology; Vaisala

Gartner Recommended Reading

Case Study: Environmental Monitoring With Sensors, AI and Predictive Modeling

Case Study: Computer-Vision-Based Environmental Monitoring

Food Safety and Traceability

Analysis By: Milly Xiang

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Adolescent

Definition:

Food safety and traceability is the ability to track the movement of a food product and its ingredients through all steps of production, processing and distribution. Food safety and traceability solutions are fragmented with diverse technology functionality to ensure food security, integrity and transparency, and enable identification of sources of food contamination and fraud, as well as waste across the entire supply chain.

Why This Is Important

Food safety and traceability is a global challenge and a big concern for the Chinese government and consumers. It is the basic requirement for human health and public safety, both necessary and challenging as it is related to the whole supply chain. There is an urgency to address diverse risks associated with food products in terms of production, processing, circulation, recall, and import or export, food waste and more, to resume consumer confidence and sustainable development of the society.

Business Impact

The causes of food safety incidents are complex (e.g., environmental pollution, overuse of chemical fertilizers and pesticides, contamination during distribution). Producers and operators are accountable for food safety as a basic social responsibility, protecting consumers while gaining operational and brand competency. A lack of transparency across the supply chain leads to inefficient collaboration and decision making among stakeholders with shared responsibility on food safety and wastage.

Drivers

- A number of effective regulations and measures (e.g., China's Food Safety Law and its implementing regulation) was released in the past few years to strengthen the supervision of food quality and safety. The food standard system has also been constantly improved. Government mandates will be a boon to the food safety use cases for associated technology and services.
- The enhancement of people's concern on health leads to increasing solicitude for food safety and traceability. Chinese residents pay more attention to the quality of food and have put forward higher requirements on and visibility of the quality, safety and sanitation status of food production, processing and distribution.
- The growing focus on sustainability and equality leads to growing concerns over food wastage across the entire supply chain. According to the United Nations, food waste accounts for 8% to 10% of global greenhouse gas emissions.
- The increasing use of Internet of Things (IoT) and remote sensing technologies in farming and agriculture helps optimize food production and enhance food safety and traceability across food manufacturers, processors, distributors and more.
- The increasing demand to facilitate robust protocols in the event of a recall or safety incident drives full transparency and real-time visibility of sources of raw materials and ingredients across each phase of supply networks.
- The adoption of cargo being monitored for temperature and other products' condition and environmental factors in food distribution and transportation helps improve food quality and safety, as well as product freshness and security for some premium products.
- Retailers including markets, grocers and sole traders will be positively impacted by improved shelf life, enhanced quality, reduced consumer returns and significantly reduced liability for selling unsafe food to consumers.

Obstacles

- The greatest obstacle to food safety is that the “farm to fork” food supply chain has too many stages, constitutes many stakeholders and vast ecosystems of participants yet to form a stable strategic and cooperative relation. Some practitioners may not demonstrate enough social responsibility.
- The existing isolated measures and regulatory requirements could struggle to capture all food safety events or scenarios.
- The challenge to establish data exchange across the ecosystems of participants in the food supply chain to support the effort of food safety and traceability remains due to the lack of trust, guidance, success practices and business models.
- Consumer perception directly relating to a string of historic food safety and traceability incidents may be difficult to change quickly. Companies will need to be cognizant of solutions that boost end-consumer confidence or reinforce collaboration and progressive change through immersive digital applications and continuous communications.

User Recommendations

For governments:

- Encourage collaboration to enforce food safety and traceability across the supply chain, and support solution development and data exchange continuously reflecting these collaborations that can mature and scale effectively.
- Build a long-term food safety and traceability management system by focusing on the key bottlenecks of quality and safety control, supported with policies, regulations and data governance.

For food supply chain organizations:

- Identify broader food traceability requirements outside of their business operations, including regulations, suppliers and customers, for context of appropriate technologies and solutions.
- Conduct food segmentation exercises and risk assessments, and prioritize technology solutions for immediate high-risk objectives (e.g., fresh fruits vs. dry good products).

- Leverage falling technology costs (e.g., new generation quick response codes or RFID) as well as increasing provider competition to drive technology penetration.

Sample Vendors

Alibaba Cloud; FoodLogiQ; Huawei Cloud; INESA; iTradeNetwork; Wiliot

Gartner Recommended Reading

Digital IQ Outlook: Food and Beverage 2022

Technology Opportunity Prism: IoT in Smart Cities

Supply Chain Brief: Are You Really Ready to Share Your Product's Origin Story?

Open Government Data

Analysis By: Uko Tian

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

Open government data is an initiative, and increasingly a set of policies, promoting transparency, accountability and value creation by making government data available to all. Public institutions become more transparent and accountable to citizens when they make their datasets publicly available. By encouraging the use, sharing and distribution of datasets, governments promote business creation and innovative, citizen-centric services.

Why This Is Important

Open government data is an important initiative in the Chinese government's digitalization plan to improve data management and service capability. Greater data transparency is expected to help the government establish higher citizen trust and more effective policy formulation and implementation. It also encourages the private sector to leverage this data to contribute to smart city services. Open data is one of the tasks listed in the government's 14th Five-Year Plan (2021 through 2025).

Business Impact

Open government data enables a new type of social service. It increases government transparency and accountability, enhancing citizens' and private sectors' engagement with the government. In practice, it's guided by regulations and laws to protect privacy and data security. Businesses can develop new products and business models based on these data. It is also a foundation for data exchange in the urban ecosystem.

Drivers

- Open government data is one of the tasks listed in the Chinese government's 14th Five-Year Plan that guarantees top-down support and management sponsorship.
- China plans to establish a national data bureau with the mandate to design and build data-related infrastructure and mechanisms to facilitate data flow, integration, and transactions while ensuring data governance and security.
- Big data management bureaus have been widely established at the provincial and municipal levels. In addition to promoting the implementation of national guidance, they also undertake the task of promoting local innovation based on shared data.
- Some provinces and cities have established a chief data officer (CDO) role within the government. One of the CDO's missions is to promote open data in government to facilitate the construction of smart cities and digital government.
- During COVID-19, both government and the public have realized the importance of using timely and accurate data from various entities to address pandemic prevention, and logistical and social challenges.

Obstacles

- Weak data governance mechanisms and risk-averse culture impede further openness of government data, as well as private sectors' willingness to participate.
- The uneven skill set in understanding data and technology at different levels of local governments hinders the data openness and fully realized data value.
- The lack of innovative use cases hinder further discovery of the value of data. This will require more data flow and exchange between government departments, and between governments, individuals and businesses.
- Data quality, scope, timeliness and tool availability are barriers to increase usage. Government open data portals are widely established. But the majority of data is static, not in real time, and in Excel or PDF format.
- Transforming government operations into a more data-driven model will bring significant changes in public governance and decision-making processes. This is a great challenge and may result in open data failing to deliver on its promised benefits.

User Recommendations

- Build up data governance mechanisms, including drafting standards on data classification, data quality, data trading and defining security levels of data. Based on this, the government should continue to drive further openness and sharing of data horizontally and vertically.
- Ensure local governments build a scheme on open data, set clear objectives, and explore possible use cases and business models to accelerate adoption.
- Explore innovation opportunities in products, services and business models, and improve decision making by leveraging the open government data.

Gartner Recommended Reading

Top Trends in Government for 2022: Data Sharing as a Program

Establish an Urban Data Exchange for Smart Cities

7 Ways to Maximize the Impact of Open Government Data: Lessons From France

Smart City Transportation Strategy

Analysis By: Bettina Tratz-Ryan, Bill Finnerty, Shivani Palepu

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

Smart city transportation strategy defines the goals for a sustainable and holistic technology and data exchange collaboration between different transportation and mobility-related urban ecosystem stakeholders. This collaboration includes a variety of different transportation modes, parking and new last-mile logistics providers. It entails advanced planning focused on accurate and measurable targets, supported by actions and control mechanisms to guarantee successful implementation.

Why This Is Important

A smart city transportation strategy can help transportation agencies in cities and regions collaborate with public and private sector stakeholders to address future mobility and transport opportunities. This includes process efficiency leading to reduced congestion, as well as improved environmental sustainability, safety, commuting time, parking and transportation cost. This strategy can also drive the local economy, improve the economic equity for residents and create walkable cities.

Business Impact

A smart city transportation strategy guarantees success in addressing challenges in the transportation ecosystem by enabling a strategic investment plan that helps local governments adequately fulfill future transportation needs. The business impact will increasingly affect the private sector, like last-mile logistics, mobility service providers, real estate and economic stakeholders. This can, for instance, support the transition to zero emissions or the deployment of autonomous technologies.

Drivers

- Urban ecosystems and local governments have to address the complexity of traffic and travel patterns in the future, and meet them with the current requirement of shared mobility, electrification of fleets, as well as new hybrid or active transport patterns.
- Local governments have begun addressing themes such as the integration of city performance management with overall city data exchanges for open data and for the development of insights across the smart city. For instance, several cities are taking steps toward creating their own mobility-as-a-aservice (MaaS) ecosystem and platform. This is a step toward deploying a fully integrated mobility strategy in a user platform accessible via smart devices, like smartphones. In some cases, cities have projects to build an open-data-based ecosystem, encompassing the entire transportation ecosystem, which can provide major future benefits by enabling an overall improvement of transportation at several different levels.
- Cities are dealing with increasingly complex problems, like congestion and pollution. These challenges highlight the growing need for technology investments in transportation and other areas as a way to solve these complex problems. These investments demand advanced planning and technological foresight, both incorporated into a smart city transportation strategy.
- The increasing number of public-private partnerships in the transportation sector work as an “eye opener” for transit authorities to acquire a more strategic approach to transportation. The Zero Emissions Delivery Zone (Santa Monica, California, U.S.) was established by the city authorities together with private partners, like Nissan and IKEA.
- In many countries and in the EU, transportation is a major contributor to national and local carbon emission and GHG. Regulations like the European Green Deal or the Infrastructure Investment and Jobs Act (U.S.) prioritize transportation projects that enable decarbonization of transport and its infrastructure.

Obstacles

- Organizational mindset limits know-how or generates skepticism when transit planners must define long-term plans that must leverage innovative transportation technologies.
- Changes in political power sometimes create a problem of continuity when fulfilling a long-term strategy.
- Local transit authorities often cannot define long-term strategic targets or KPIs that are specific, measurable, attainable, relevant or time-bound. This challenge generates major obstacles in defining a clear strategic course, which hinders the benefit extracted from transportation technologies in the long run.
- Limited budget allocation or ineffective strategy in relation to data analytics. An inability to efficiently use data to support decision processes will be a substantial obstacle to formulating a successful smart city transportation strategy.

User Recommendations

- Establish data governance policies that enable a mobility and transport data ecosystem with an efficient data exchange across numerous mobility and infrastructure providers. Enable transportation planning and an overall improvement of transportation efficiency.
- Ensure your smart city transportation strategy assesses the impact of these socioeconomic changes and defines appropriate action. Spatial designs on road infrastructure need to align with urban planning for climate adaptation, heat islands and greening of spaces.
- Develop specific, measurable and time-bound targets in support of your smart city transportation strategy. This insight facilitates choosing the right technology to reach those targets. Focus on KPIs and other references, like ISO 37120 or ITU-T.
- Build a technology radar to provide visibility of all major transportation technologies coming up in the next 10 years. This tactic enables a greater understanding on how technology helps your organization fulfill its strategy.

Sample Vendors

Hexagon; MaaS Global; Moovit; Mott MacDonald; NTT DATA; Optibus; PTV Group; Trafi

Gartner Recommended Reading

Quick Answer: How Can Transit CIOs Leverage Micromobility to Strengthen Public Transportation?

Market Insights: Unique Regional Dynamics Require Tailored Strategies for Smart Cities in Asia

Quick Answer: How Can Transit CIOs Leverage Micromobility to Strengthen Public Transportation?

Top Strategic Technology Trends in Manufacturing and Transportation for 2023 — Presentation Materials

Renewable Energy

Analysis By: Arnold Gao

Benefit Rating: Transformational

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Renewable energy refers to energy types that are generated from natural, renewable resources, such as sunlight, wind or water. They are the opposite of fossil fuels, like coal and gas, which are finite energy sources. The term “renewable energy” is often interchangeable with “sustainable energy” or “green energy.”

Why This Is Important

The world is facing a serious challenge with climate change. While the COVID-19 pandemic has temporarily reduced emissions, carbon dioxide levels are still at record highs, and rising. Countries representing more than 70% of the world economy have committed to achieving net zero emissions by 2050, while China has committed to reaching its carbon emission peak before 2030 and carbon neutrality by 2060. Renewable energy is one of the most important solutions toward achieving this ambitious goal.

Business Impact

With the implementation of the carbon tax and cap-and-trade programs, enterprises that adopt renewable energy will benefit commercially. For example, in 2022 Tesla made $1.78 billion by selling carbon credits, while in China carbon trading has been introduced into the power industry. Other benefits of adopting renewable energy include saving costs on energy consumption, improving public image and reputation, reducing geopolitical risk on energy prices in the long run, etc.

Drivers

- **Reduce energy bills:** By installing solar panels and wind turbines, enterprises can use renewable energy to support their operations and reduce energy costs. If the business produces more renewable energy than it needs, it can sell the energy back to the grid as a source of extra revenue.
- **Secure energy supply:** The prices of fossil fuels change over time, not only due to supply and demand, but also impacted by geopolitical situations. Renewable energy can help to mitigate the risk of price fluctuations and secure the supply.
- **Commercial incentives supported by the government:** Renewable energy can help enterprises become exempt from paying carbon tax or receive subsidies from the government, especially in the manufacturing and energy industries.
- **Technology development:** Technologies that reduce the cost of generating renewable energies are helping to drive the adoption rate.
- **Future-proofing:** The use of renewable energy will become mainstream, not only because governments around the world have made commitments, but also because fossil fuels will run out one day. Switching sooner may offer competitive advantages or even new business models to enterprises with early experience in renewable energy.

Obstacles

- Renewable energy cannot be generated when the sun doesn't shine, or the wind stops blowing. Its electricity generation does not match the peak demand hours and is somewhat unpredictable.
- The use of batteries for power storage can help to address the instability challenge of renewable energy. However, the cost of power storage is still very high in the event of massive adoption.
- The production and operation costs of renewable energy are lower than fossil fuel energy. However, the capital cost of initial installation is higher and requires fossil fuels as a backup.
- Renewable energy systems are usually decentralized, located in various locations and need to work together through the power grid. However, most of the existing transmission system was built for fossil fuels.
- Renewable energy is not just about technology, it is a multi-billion-dollar industry that may disrupt the existing energy paradigm and is unlikely to be successful without the endorsement from the government/regulator. The lack of policies and subsidies that favor renewable energy will hinder its wide acceptance.

User Recommendations

- Seek information from the central or local government as to whether any policies or subsidies are in place to support renewable energy.
- Measure the organization's carbon emissions and set up a plan to reduce its carbon footprint by evaluating how renewable energy can help to reduce the cost of purchasing carbon credits.
- Calculate the costs and benefits of switching to renewable energy and build a business case for executive leaders.
- Work with vendors to build a renewable energy system to support business operations and eventually replace fossil fuel energy.

Sample Vendors

Envision Group; Goldwind; Huawei Technologies; LONGi Green Energy Technology; Tongwei Group

Computer Vision for Smart Cities

Analysis By: Tracy Tsai

Benefit Rating: Transformational

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Computer vision (CV) is a process and set of technologies that involve capturing, processing and analyzing real-world images and videos to allow machines to extract meaningful, contextual information from the physical world. CV for smart cities in China includes, but is not limited to, various applications such as public surveillance systems, traffic flow control, or monitoring crowd gathering, etc.

Why This Is Important

CV is critical to enable smart cities operations more efficiently and effectively to validate citizen identification for services or public transportation and monitor communities, natural disasters, environmental pollution, traffic flow, or restaurant kitchen food safety. It is also important for managing and automating public safety with video surveillance and facial recognition 24/7; scanning personal belongings and luggage at stations and performing physical tasks with CV-enabled autonomous drones, vehicles or robots.

Business Impact

The major business impacts of computer vision for smart cities include:

- Enhancing government intelligence with CV-enabled Internet of Things or healthcare.
- Empowering law enforcement to search and identify suspects more effectively.
- Improving citizen satisfaction in traffic flow or face scanning for a fast pass.
- Reducing cost and risks for labor-intensive tasks such as civil engineering inspecting tunnel walls.
- Mitigating the risk of citizen sickness caused by bad food processed in restaurant kitchens.

Drivers

- Due to the large populations, smart cities in China particularly value CV to automate tasks for cost reduction and better efficiency. For example, drones, robots or surveillance cameras perform tasks challenging for humans physically or capacitywise.
- Continuous expansion of CV applications that enhance the quality of smart city initiatives is driving adoption. These applications include service robots, street parking violations, retinal image diagnosis for diabetes in elderly people, finding missing people, optical character recognition (OCR) to validate citizen signatures, and civil engineering inspections.
- Due to the measurable outcomes delivered through initial deployment, all levels of government organizations strive to accelerate and scale the implementation of CV to enhance their administrative and service capabilities.
- Maturity of technologies and a large number of solution providers in China make it easier for smart cities to choose and adopt the solutions faster. In addition, higher competition is pushing vendors to innovate faster, explore new use cases, and potentially offer more competitive prices.

Obstacles

- Though there are lots of potential CV use cases in smart cities, the question is whether they make business sense to invest in. It is getting difficult to find new CV use cases with as high volume as surveillance, except for niche applications such as satellite images for urban planning and sustainability initiatives.
- CV vendors do not invest in niche use cases that cannot be scaled and require significant tailored efforts especially good-quality data. As a result, it is difficult for governments to find off-the-shelf solutions for such cases.
- A gap in IT maturity exists among cities, provincial and central governments. The lack of central data and application governance results in different standards and rules in selecting vendors and also duplication of efforts and investments.
- Citizens' increasing concerns about their data privacy lead to resistance to applications.
- The accuracy of the models may decay after a period of time. This could generate following model operation/maintenance cost.

User Recommendations

- Assess existing applications or processes to identify where CV can make the applications and processes more intelligent with measurable business outcomes.
- Build a CV application marketplace platform by collecting successful CV cases, models, data and vendor lists, and provide access to other cities.
- Form a centralized IT department at the national government level to support local governments in managing the governance of data, applications, vendor selection and security requirements. The centralized IT department can provide relevant information and build a standard for local governments to improve the success rate of CV projects.
- Gain citizens' trust by building privacy protection guidance for application development and assessment.

Sample Vendors

Alibaba Cloud; Baidu; CloudMinds Robotics; DJI; Huawei Technologies; Megvii; SENSCAPE Technologies; SenseTime; Tencent; YITU Technology

Gartner Recommended Reading

Emerging Tech: Revenue Opportunity Projection of Computer Vision

Emerging Technologies: Emergence Cycle for Computer Vision

Climbing the Slope

EVs and Charging Infrastructure in China

Analysis By: Roger Sheng

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

Electric vehicles (EVs) and charging infrastructure create a new energy ecosystem for transportation. EVs use battery power as a replacement for the internal combustion engine (ICE), and charging infrastructure provides recharging services to EVs/plug-in hybrid EVs (PHEVs). Charging infrastructure is normally provided by EV makers (for fast charging), charging service providers (for commercial charging services) and private parking lots (for individual users).

Why This Is Important

China has made EVs one of its important industry initiatives for realizing carbon neutrality by 2060. In 2022, over 4.9 million EVs were sold in China (reflecting 105% annual growth), which made up approximately 60% of the total global EV market. To support the fast growth of EVs, more than 5.2 million charging piles and stations (1.8 million public and 3.4 million private) had been installed in China by the end of 2022, with nearly 100% annual growth.

Business Impact

The penetration growth of EVs and charging infrastructure in China will intensify the revolution of the automotive, transportation and energy industries. Automotive OEMs are producing more EVs to leverage more government subsidies and credits from carbon emission reductions. Energy and utility providers, meanwhile, need to develop new business for EV charging infrastructure. The adoption of EVs also allows the transportation industry to improve operational efficiency with lower carbon emissions.

Drivers

- The **Chinese government** is the largest stakeholder in promoting the adoption of EVs and charging infrastructure. Its goal is to meet its carbon-neutrality objectives and build a revolutionary world-leading large-scale energy industry. Individual EV buyers can receive government subsidies for new EV purchases and charging pile installations. In most major cities where car licensing is limited, consumers can get a free license plate for EVs, which is a major reason they buy EVs instead of ICE vehicles. In public transportation, the government spends billions of dollars on subsidies for the electrification of city buses and taxis. In 2023, it announced a plan to promote EVs and charging infrastructure in the rural market after the maturity of the urban market.

- Local emerging EV **automakers** have had outstanding growth performance in China compared with traditional ICE vehicle OEMs. Improved product designs, "intelligent customer experience" and extended driving distances are attracting more consumer buyers and transportation service providers, especially in cities where more charging infrastructure services are available. 2022 was a turning point for China's EV market; BYD reported it sold approximately 1.8 million EVs and PHEVs in China, reflecting over 200% annual growth, which outperformed Tesla.

- **Utility companies** are investing in EVs and charging infrastructure for business growth. State-owned power utility companies are offering lower prices at night, reducing the cost of EV charging. Fast-charging services are considered a new revenue opportunity wherein utility companies can provide high-power-charging infrastructure.

- **Power-charging service providers** are aggressively expanding their services in public areas by building more charging piles and stations in commercial areas, along transportation routes and in residential zones. Battery-changing services are an emerging solution that can reduce charging hours. Chinese EV brand NIO is promoting its battery-changing service as a differentiator.

Obstacles

- **Shorter driving distance compared with traditional ICE vehicles:** Although more EVs are being promoted that support battery driving cycles of more than 500 km, the real driving distance per charging is usually impacted by driving conditions and the weather.

- **Slower charging performance compared with oil and gas:** It usually takes more than eight hours to fully charge an EV in the normal charging mode and around two hours in a fast-charging station.

- **High battery cost:** Currently, the battery is the single most expensive part of an EV to the point that the battery cost decides the EV's price.
- **Other new energy technologies:** Hydrogen-energy-based fuel cell technology is one alternative for vehicles that has received more interest from government and major automakers.

User Recommendations

EV and PHEV manufacturers:

- Cooperate with key components and subsystem providers to build a local manufacturing supply chain for close-to-market advantage.
- Improve the power efficiency of battery and charging systems by using wideband-gap semiconductors.
- Cooperate with service providers to develop smart cockpit and advanced driver assistance systems for EVs to improve the intelligent customer experience.
- Develop innovative business models, such as battery-changing services, to improve the user experience and EV operational efficiency.

Power-charging service providers:

- Partner with digital map and navigation service providers to provide location charging facility information for EV users.
- Redefine the price matrix for different EV users (individual, commercial or public) by different charging service areas (residential, commercial or public) to maximize infrastructure ROI.
- Cooperate with EV makers to improve charging service efficiency and increase utilization across different car brands.

Sample Vendors

BYD; Li Auto; NIO; State Grid Corporation of China; Tesla; Wanbang Digital Energy; XPENG

Gartner Recommended Reading

Forecast: Electric Vehicle Shipments, Worldwide, 2022-2032

Hype Cycle for Connected, Electric and Autonomous Vehicles, 2023

Market Guide for Electric Vehicle Charging Solutions

IoT in Smart Cities

Analysis By: Milly Xiang

Benefit Rating: Transformational

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

The Internet of Things (IoT) is a key pillar of smart city development. Cities use the network of dedicated IoT devices, such as connected sensors, cameras and meters, to collect data and interact with their internal states and/or the external environment. IoT applications give cities the ability to remotely monitor, manage and control various city assets and spaces, as well as to create continuous, contextualized and actionable insights to support city administration and citizen engagement.

Why This Is Important

The effective and efficient use of IoT technology in cities presents great potential to help cities solve urbanization challenges and improve the quality of life across a wide range of sectors, including mobility, safety, sustainability and well-being. IoT is an indispensable part of cities' urban infrastructure renewal, China's "New Infrastructure" initiative and the transition to data-driven city administration, and urban ecosystem collaboration and planning.

Business Impact

IoT deployment affects:

- **Government organizations** — Increase the visibility of city infrastructure status and to improve decision making and planning.
- **Citizens** — Change people's environments in all aspects of urban experience and government services, including their standard of living, commute, entertainment options and more.

- **Local industries and service providers** — Harness the IoT data gathered through sensors to analyze user behavior, as well as to optimize business models and service offerings.

Drivers

- Government and urban ecosystem players have seen proof of value in past IoT deployments for its potential in providing unification and context to various data in cities and turning it into actionable insights. These insights support enhancing administration efficiency, sustainability, safety and quality of life.
- Cities in China are starting to shift from an infrastructure-centric approach toward a data-centric approach in their IoT strategies. This shift helps unlock more value out of the IoT-enabled infrastructure and data assets when these deployments are planned and leveraged across different government organizations and across the entire urban ecosystem.
- Technologies such as AI, edge computing, digital twin and more add to the value of IoT adoption by shifting from simple monitoring to driving more complicated applications through prediction and simulation.
- In China, the earliest cities using IoT to transform processes (e.g., Beijing, Hangzhou, Shanghai and Shenzhen) provide a blueprint for smart city infrastructure and services for less technologically integrated cities.
- Progress is accelerating in policies or guidelines, stimulating IoT adoption and defining how to securely exploit the value of data in a multistakeholder environment, while complying with privacy regulations and relieving security and privacy concerns limiting IoT adoption.
- Cities are exploring additional funding sources to release the initial capital expenditure and accelerate adoption. For example, some cities look into public-private-partnership models, like management contracts, operating contracts, long-term leasing, build-operate-transfer models, design-build-own models and others.
- The effects of climate change and the move toward renewable energy has pushed the revolution of smart cities to provide all essential needs to the public without causing many negative impacts on the environment. This goal requires cities to upgrade their tools to monitor and respond to changing urbanization dynamics.

Obstacles

- **Development path:** Cities struggle with the complex goal of achieving growth while keeping pace with technology, budgetary reality, and citizens and businesses' changing expectations.
- **Technical immaturity:** Most IoT technologies are still two to five years from mainstream adoption; some may require over five years.
- **Security issues:** IoT leads security concerns, beyond cyber, extend to the safety of residents and the reliability of the physical environment.
- **Data use:** The lack of data interoperability standards within and across domains.
- **New integration challenges:** Compounded by the lack of industry standards, integration challenges are inherently introduced by new IoT endpoints, event-driven data streaming and new analytic-based workflows to drive city applications.
- **Human factor:** Government staff members and stakeholders resist IoT without seeing its direct benefits. Many foresee challenges to changing behaviors and work habits, even less job opportunities.

User Recommendations

- Prioritize developing features for the accelerated initiatives shaping the long-term drivers (e.g., well-being, sustainability), and fulfilling the needs of both public and private stakeholders in different subsegments.
- Build IoT-enabled business solutions with enhanced integration or analytics capabilities to solve specific business problems, driving outcomes around safety, efficiency, well-being and sustainability.
- Migrate IoT solutions into a digital urban ecosystem enabler by investing into adjacent technologies and technology alliances around IoT applications, third-party integration tools, machine learning, etc.
- Build skills around technologies like AI, edge computing and digital twin, and develop a phased strategy to align IoT deployments with the maturity of these technologies.
- Observe legal and ethical events relevant to IoT, follow closely on regulatory and standards progress. Review strategy and policies on a regular basis.

Sample Vendors

Alibaba Cloud; Baidu Cloud; H3C; Hikvision; Huawei; iotblue; Tencent Cloud; Terminus Technologies; Unicom Digital Technology

Gartner Recommended Reading

Technology Opportunity Prism: IoT in Smart Cities

Predicts 2023: Sustainable Smart City Decision Making Using Urban Data

Infographic: IoT Use-Case Prism for Sustainability and ESG

Natural Language Technologies in Smart Cities

Analysis By: Tracy Tsai

Benefit Rating: High

Market Penetration: More than 50% of target audience

Maturity: Early mainstream

Definition:

Natural language technology (NLT) encompasses the technologies and methods that enable intuitive forms of communication between humans and systems, and their analysis. NLT includes natural language understanding, natural language generation, text analytics, machine translation, speech to text and others. Smart cities use NLT applications and services to interact with their citizens or businesses, improving the operational outcomes of both external- and internal-facing processes.

Why This Is Important

NLT enables China's smart cities' operation and citizen services to be more efficient, effective and intelligent. Given the large populations and multiple tiers of cities in China, streamlined processes between systems and humans and scalability of quality and reliability are challenges for smart cities and government digital business optimization and transformation. Examples include hotline citizen services and centralized smart cities commander dashboard using NLT to retrieve the information.

Business Impact

The business impacts of NLT in smart cities in China are amplified, given China's large populations, diversity of local dialects and multiple tiers of city operations.

- Improving citizen satisfaction and engagement via intuitive natural language interactions.
- Augmenting government workforces with better capabilities to perform via virtual assistants.
- Transforming smart cities with new ways of operations to be more agile, effective and efficient via text analytics and other NLT technologies.

Drivers

- The Chinese government's strong interest in the adoption of NLTs, such as text analytics, emotional AI and other applications, to improve its operations or citizen services.
- The demand for smart cities and government to streamline citizen services more efficiently and effectively. For example, citizen hotlines equipped with voice-enabled virtual assistants to serve citizens with different local dialects and accents.
- NLTs are an intelligent and effective way to detect, analyze and monitor social media comments to manage the societal order and avoid social risk.
- There are more Chinese vendors releasing large language models that are trained with context to China, gaining more attraction for its general purpose capabilities and improvement of user experiences.
- Growing adoption of business intelligence and analytics with NLT-enabled applications, lowering the adoption barrier for citizen scientists in the government and public sector.
- The need to migrate government services from offline and online channels by using chatbots or virtual assistants.
- NLT technology has been greatly improved by deep neural network (DNN) machine learning (ML) methods. These new capabilities, combined with existing methods, enable improved functionality.

Obstacles

- The multiturn conversation is still not fully intelligent and requires continual maintenance and model optimization. Citizens' acceptance of chatbots or voice-enabled virtual assistants is still limited to basic information and support, and not for solving complex problems.
- Highly specific language models (such as low-resource Chinese dialects or variants) need to be created by vendors to improve the performance of NLT across different government domains.
- There are concerns over citizen privacy and security when using NLT for monitoring the public.
- A lack of skilled computational linguists with machine learning (ML) and data science background hinders adoption.

User Recommendations

- Identify your organization's objectives and the incremental value-add to citizens that NLT-based applications will bring.
- Develop use cases that improve customer/citizen services, such as streamlined processes and intuitive user experiences, to increase their engagement with governments.
- Combine NLT with location intelligence or digital twins to support use cases blended with digital and physical worlds for semantic search, data analytics, predict and prescribe recommendations.
- Collaborate with line-of-business (LOB) stakeholders on how to scope your NLT product requirements, features and experiences, such as building a shared understanding and common agreement on the taxonomy and ontology, to ensure the data scope and quality.
- Request vendors to provide an inference model for testing with citizen data, and support the maintenance of models by continuously optimizing it with new sets of data for quality and accuracy.

Sample Vendors

Alibaba Group; AISpeech; Baidu; Emotibot; iFLYTEK; Microsoft; Sobot Technologies; Tencent; Xiao-i; Zhuiyi

Gartner Recommended Reading

Market Guide for AI Software, China

Market Guide for Artificial Intelligence Startups, Greater China

Quick Answer: China Perspective — Frequently Asked Questions on ChatGPT and Large Language Models

Government Cloud in China

Analysis By: Kevin Ji, Evan Zeng, Carolin Zhou

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

The government cloud is a form of industry cloud that is constructed by certified cloud service providers, in either the government's on-premises data center or in an authorized colocation, and hosted by a government agency. The goal is to achieve data sharing, operation efficiency, confidential data protection and citizen service innovation.

Why This Is Important

Most government agencies have built cloud infrastructure in the past two to three years, which enabled them to present good public service agility while responding to the pandemic. Based on new initiatives around digital government, such as east-data-west-computing and green data center, most of the Chinese government agencies plan to improve the cloud service for compliance and business agility and enable innovative services, especially in citizen service, through digital channels.

Business Impact

Government cloud has a significant business impact as:

- The government cloud deployment model can fulfill the requirements of data sovereignty and strong access authentication, which are hard to achieve in commercial public cloud services models.

- Government agencies pursue new scalable cloud computing technology to replace current legacy infrastructure but lack the talent to build cloud stacks from scratch.
- Governments can build the capability to manage the private cloud, engaging new vendor ecosystems that can enable outsourced private cloud.

Drivers

- **Improve public services' efficiency:** The fast-qualified service initiative is a well-known flagship government solution in China. In the past, citizens spent a great deal of time following complex processes requested by different government agencies to deal with a single request of public service. During the pandemic, provincial government agencies required a trace-and-locate ecosystem to help citizens access things necessary to get through the pandemic. Hence, government agencies needed to leverage cloud services on agility and innovation.
- **China IT stack localization initiative:** Government agencies planned to use cloud service products whose intellectual properties (IPs) are owned by national companies. Government agencies established the technology localization initiative to build an authorized product list, replacing the traditional infrastructure during cloud migration.
- **New infrastructure construction initiatives such as the east-data-west-computing initiative:** The Chinese government will build eight national computing hubs and approved plans for 10 national data center clusters, indicating the completion of the overall layout for the national integrated big data center system (see Five Things to Know About China's Mega East-West Data Center Plan, Nikkei Asia).

Obstacles

- **Lack of talent pool:** Existing resources are focused on supporting traditional IT infrastructure. It is hard to engage enough talent because of the challenge an attractive salary and planned career path poses.
- **Data sharing challenge:** If a government agency plans to build a solid data structure across its systems to process data analysis, it faces a significant challenge in modernizing the application architecture and standardizing the data structure across different agencies.
- **Emerging IT ecosystem:** The IT stack localization is a long-term plan to support cloud stack replacement. At this moment, it may face the challenge of low maturity of open-source software or low compatibility of self-IP hardware systems.
- **Cost reduction:** After the pandemic, government agencies need to optimize the cost to make operations more efficient. It may slow down the future IT construction plan.

User Recommendations

- Align digital government initiatives, such as city-smart brain, with stakeholders and engage high-value delivery first, such as digital channel services and cost optimization services. It is easy to set procurement priorities accordingly.
- Get certified by Chinese new infrastructure construction initiatives, such as IT stack localization or AI initiatives, to gain infrastructure investment and focus on application tuning for business results.
- Build suitable data governance to consolidate and share the data with authorized agencies or apps for citizens (see Quick Answer: How Should Chinese Enterprises Better Deliver Data Monetization Regarding “20 Data Measures”).
- Change the resource-funding process from asset procurement (capital cost) to a service subscription model (operational cost) to fit the new cloud service usage practice.

Sample Vendors

Alibaba Cloud; China Telecom; China Unicom; Huawei; Inspur; New H3C; Tencent

Gartner Recommended Reading

Top Trend in Government: Case Management as a Service

Appendixes

See the previous Hype Cycle: Hype Cycle for Smart City and Sustainability in China, 2022

Hype Cycle Phases, Benefit Ratings and Maturity Levels

Table 2: Hype Cycle Phases

(Enlarged table in Appendix)

Phase	Definition
Innovation Trigger	A breakthrough, public demonstration, product launch or other event generates significant media and industry interest.
Peak of Inflated Expectations	During this phase of overenthusiasm and unrealistic projections, a flurry of well-publicized activity by technology leaders results in some successes, but more failures, as the innovation is pushed to its limits. The only enterprises making money are conference organizers and content publishers.
Trough of Disillusionment	Because the innovation does not live up to its overinflated expectations, it rapidly becomes unfashionable. Media interest wanes, except for a few cautionary tales.
Slope of Enlightenment	Focused experimentation and solid hard work by an increasingly diverse range of organizations lead to a true understanding of the innovation's applicability, risks and benefits. Commercial off-the-shelf methodologies and tools ease the development process.
Plateau of Productivity	The real-world benefits of the innovation are demonstrated and accepted. Tools and methodologies are increasingly stable as they enter their second and third generations. Growing numbers of organizations feel comfortable with the reduced level of risk; the rapid growth phase of adoption begins. Approximately 20% of the technology's target audience has adopted or is adopting the technology as it enters this phase.
Years to Mainstream Adoption	The time required for the innovation to reach the Plateau of Productivity.

Source: Gartner (July 2023)

Table 3: Benefit Ratings

Benefit Rating ↓	*Definition* ↓
Transformational	Enables new ways of doing business across industries that will result in major shifts in industry dynamics
High	Enables new ways of performing horizontal or vertical processes that will result in significantly increased revenue or cost savings for an enterprise
Moderate	Provides incremental improvements to established processes that will result in increased revenue or cost savings for an enterprise
Low	Slightly improves processes (for example, improved user experience) that will be difficult to translate into increased revenue or cost savings

Source: Gartner (July 2023)

Table 4: Maturity Levels

(Enlarged table in Appendix)

Maturity Levels	Status	Products/Vendors
Embryonic	In labs	None
Emerging	Commercialization by vendors Pilots and deployments by industry leaders	First generation High price Much customization
Adolescent	Maturing technology capabilities and process understanding Uptake beyond early adopters	Second generation Less customization
Early mainstream	Proven technology Vendors, technology and adoption rapidly evolving	Third generation More out-of-box methodologies
Mature mainstream	Robust technology Not much evolution in vendors or technology	Several dominant vendors
Legacy	Not appropriate for new developments Cost of migration constrains replacement	Maintenance revenue focus
Obsolete	Rarely used	Used/resale market only

Source: Gartner (July 2023)

Document Revision History

Hype Cycle for Smart City and Sustainability in China, 2022 - 29 July 2022

Hype Cycle for Smart City and Sustainability in China, 2021 - 9 July 2021

Hype Cycle for Smart City and Sustainability in China, 2020 - 31 July 2020

Hype Cycle for Smart City and Sustainability in China, 2019 - 26 July 2019

Hype Cycle for Smart City and Sustainability in China, 2018 - 18 July 2018

Hype Cycle for Smart City and Sustainability in China, 2017 - 28 July 2017

Hype Cycle for Smart City and Sustainability in China, 2016 - 14 July 2016

Hype Cycle for Smart City and Sustainability in China, 2015 - 27 July 2015

Hype Cycle for Green IT and Sustainability in China, 2014 - 21 July 2014

Hype Cycle for Green IT and Sustainability in China, 2013 - 29 July 2013

Hype Cycle for Green IT and Sustainability in China, 2012 - 2 August 2012

Recommended by the Authors

Some documents may not be available as part of your current Gartner subscription.

Understanding Gartner's Hype Cycles

Tool: Create Your Own Hype Cycle With Gartner's Hype Cycle Builder

Maverick Research: Metaverse Is the Ally for Smart Cities and Urban Sustainability

Predicts 2023: Sustainable Smart City Decision Making Using Urban Data

Build Value Story for IoT Smart Cities Use Cases

Technology Opportunity Prism: IoT in Smart Cities

Smart City Funding Models: It's Time to Get Creative

Table 1: Priority Matrix for Smart City and Sustainability in China, 2023

Benefit	*Years to Mainstream Adoption*			
↓	***Less Than 2 Years*** ↓	***2 - 5 Years*** ↓	***5 - 10 Years*** ↓	***More Than 10 Years*** ↓
Transformational	Computer Vision for Smart Cities	IoT in Smart Cities	Data Risk Assessment Renewable Energy Smart and Sustainable Building	

Benefit	*Years to Mainstream Adoption*			
↓	***Less Than 2 Years*** ↓	***2 - 5 Years*** ↓	***5 - 10 Years*** ↓	***More Than 10 Years*** ↓
High	5G for China Government Cloud in China	Data Governance Digital Twin of a Citizen Digital Twins of Government Environment Monitoring and Management EVs and Charging Infrastructure in China Food Safety and Traceability Intelligent Street Pole Interjurisdictional Government Services Natural Language Technologies in Smart Cities Privacy in China Urban Energy Management Platform Urban Waste Management Water Management Analytics	City Asset Management CPS Security in China Heavy-Duty EV Charging Intelligent Connected Infrastructure Open Government Data Smart City Transportation Strategy	
Moderate		Data and Analytics for Good		
Low				

Source: Gartner (July 2023)

Table 2: Hype Cycle Phases

Phase	*Definition*
Innovation Trigger	A breakthrough, public demonstration, product launch or other event generates significant media and industry interest.
Peak of Inflated Expectations	During this phase of overenthusiasm and unrealistic projections, a flurry of well-publicized activity by technology leaders results in some successes, but more failures, as the innovation is pushed to its limits. The only enterprises making money are conference organizers and content publishers.
Trough of Disillusionment	Because the innovation does not live up to its overinflated expectations, it rapidly becomes unfashionable. Media interest wanes, except for a few cautionary tales.
Slope of Enlightenment	Focused experimentation and solid hard work by an increasingly diverse range of organizations lead to a true understanding of the innovation's applicability, risks and benefits. Commercial off-the-shelf methodologies and tools ease the development process.
Plateau of Productivity	The real-world benefits of the innovation are demonstrated and accepted. Tools and methodologies are increasingly stable as they enter their second and third generations. Growing numbers of organizations feel comfortable with the reduced level of risk; the rapid growth phase of adoption begins. Approximately 20% of the technology's target audience has adopted or is adopting the technology as it enters this phase.
Years to Mainstream Adoption	The time required for the innovation to reach the Plateau of Productivity.

Phase	Definition

Source: Gartner (July 2023)

Table 3: Benefit Ratings

Benefit Rating	Definition
Transformational	Enables new ways of doing business across industries that will result in major shifts in industry dynamics
High	Enables new ways of performing horizontal or vertical processes that will result in significantly increased revenue or cost savings for an enterprise
Moderate	Provides incremental improvements to established processes that will result in increased revenue or cost savings for an enterprise
Low	Slightly improves processes (for example, improved user experience) that will be difficult to translate into increased revenue or cost savings

Source: Gartner (July 2023)

Table 4: Maturity Levels

Maturity Levels ↓	*Status* ↓	*Products/Vendors* ↓
Embryonic	In labs	None
Emerging	Commercialization by vendors Pilots and deployments by industry leaders	First generation High price Much customization
Adolescent	Maturing technology capabilities and process understanding Uptake beyond early adopters	Second generation Less customization
Early mainstream	Proven technology Vendors, technology and adoption rapidly evolving	Third generation More out-of-box methodologies
Mature mainstream	Robust technology Not much evolution in vendors or technology	Several dominant vendors
Legacy	Not appropriate for new developments Cost of migration constrains replacement	Maintenance revenue focus
Obsolete	Rarely used	Used/resale market only

Source: Gartner (July 2023)