Hype Cycle for Smart City Technologies and Solutions, 2023

Published 31 July 2023 - ID G00788973 - 117 min read

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Initiatives: Government Verticals Digital Innovation and Application Modernization

> A smart city is designed to achieve a sustainable and people-centric quality of life by creating an intelligent urban ecosystem. This research helps government CIOs assess emerging technologies, practices, urban principles and solutions to collaborate and deliver sustainable societal 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

Smart city technology and solutions are instrumental in developing transparent and citizen-centric urban outcomes, delivered by local governments in alignment with an intelligent urban ecosystem. Cities have to meet the challenges of economic instability in times of high cost of living, social distress and impacts through climate change by applying digital strategies to augment policy and service requirements through data-driven insights. In this context, digital capabilities have moved beyond simple service delivery and are poised to increase simulation of real-time events for expansive impact analysis, while creating strategic outcomes that directly improve sustainability and equity. Leveraging data orchestration and data exchanges will enable cross-regional synergies and service capabilities in a hosted “smart city as a service” environment. Those capabilities become an increasing differentiator in many cities in emerging economies that are building new infrastructure, new housing districts, and new industry sectors and zones.

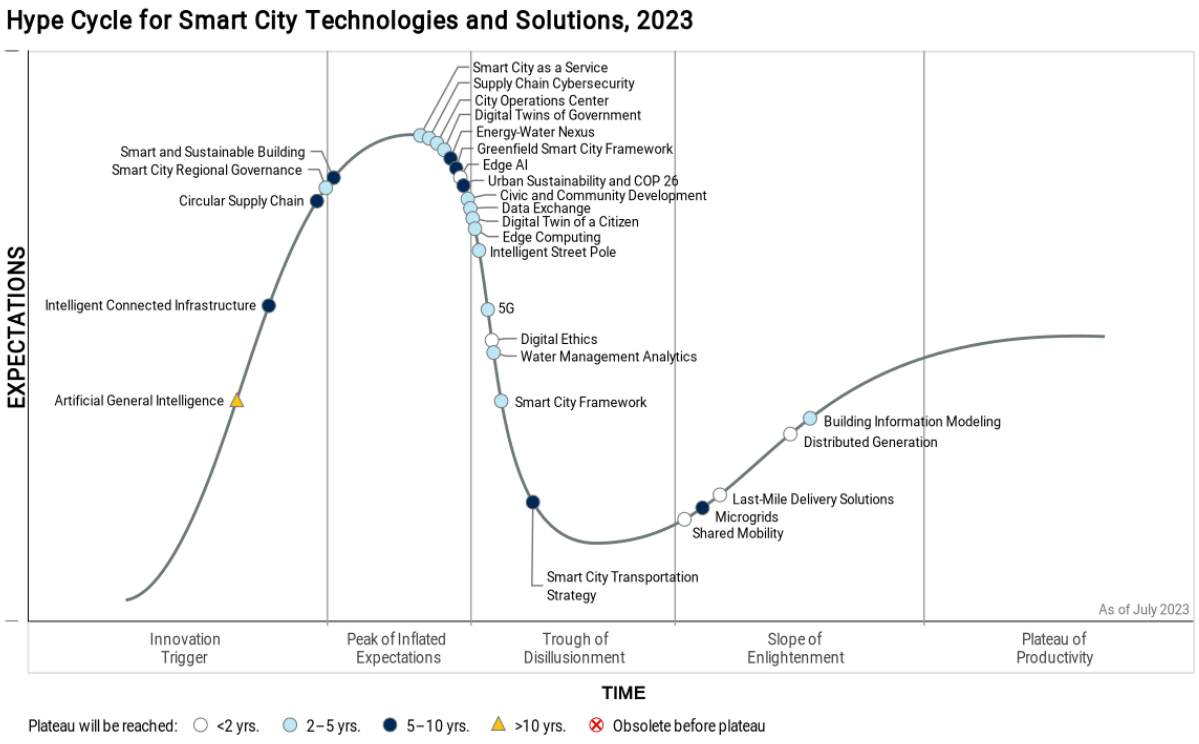
The Hype Cycle

The 2023 Hype Cycle for Smart City Technologies and Solutions focuses on the holistic ecosystem approach made possible by data exchanges and digital twin use cases. Trends in analytics at the service delivery point, decarbonization, last-mile logistics, mobility and building options are opening the door for an experience delivered at the edge of the service delivery network, thus calling for 5G and broadband rollouts. Intelligent edge will be key to developing autonomous driving, as well as street poles that are more than just streetlights and integrate multiple functions.

One of the beneficiaries of data integration, as well as of increasing intelligence at the edge, is smart city as a service, along with approaches on sustainability- and community-driven strategies, which become accelerating competencies. Generative AI provides a promising opportunity to synthesize these large, varied datasets to aid in addressing complex issues in local government. In particular, digital twin technology will be a beneficiary of data orchestration and governance, which explains the transformational speed of digital twin of citizens and government. Innovations like water management analytics, microgrids and energy-water nexus are high priorities in the smart city framework discussions around cities' climate change charters. [1] With the 2021 United Nations Climate Change Conference (COP26) adding biodiversity and urban sustainability opportunities into focus, we are focusing on the sustainability and COP26 outcomes. Artificial generative intelligence has been accelerating, but while the technology capability could be embedded in many use cases, citizen trust toward artificial intelligence (AI) ethics and policy will require extensive guardrails for its success.

Initiatives of the World Economic Forum seek to rebuild society through the Fourth Industrial Revolution in urban centers, and project that sustainability and business development, especially in cities, will increase. These initiatives provide an extension of the circular urban environment approach. As in previous years, the maturity of the technology solutions and platforms is farther ahead than the business and city outcomes that they are promising to generate.

Figure 1: Hype Cycle for Smart City Technologies and Solutions, 2023



The Priority Matrix

Many technologies have a transformational or high impact on smart cities, but will take a longer time to achieve their benefits. As a result, city CIOs and urban planners will implement the solutions over longer periods to generate outcomes and ROI. Many of the benefits can be supported using data analytics and data exchange to optimize city operations, along with the intelligent urban ecosystem, or to drive long-term sustainable and inclusive outcomes. Circularity strategies, especially in the supply chain of urban consumption or, in some megacities, in terms of overconsumption, are increasing quickly, leading to a hyped discussion on methodology and stakeholder involvement.

Innovations like data exchanges will provide transformational experiences to city services and will become mainstream in the next five years. Becoming mainstream means that the rapid increase of automated transactions will support contextualization of service delivery at the location where the service is needed. For example, this acceleration is needed for smart buildings and city operations centers. Those will be maturing, along with the circular economy, in 10 years or less.

High benefits will be generated in up to five years from innovations such as 5G, in conjunction with building information modeling in smart buildings and campuses. CIOs will require those technologies to capture and analyze data for operational efficiency (for example, in transportation and shared mobility), and for energy and resource management. Digital representation of urban situations through digital twins will show benefits over an extended time period of up to 10 years as joint governance on urban objectives and vision turn into actionable roadmaps.

Table 1: Priority Matrix for Smart City Technologies and Solutions, 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	Distributed Generation	City Operations Center Data Exchange Edge Computing Smart City Framework	Circular Supply Chain Greenfield Smart City Framework Smart and Sustainable Building Urban Sustainability and COP 26	Artificial General Intelligence
High	Digital Ethics Edge AI Last-Mile Delivery Solutions	5G Building Information Modeling Civic and Community Development Digital Twin of a Citizen Digital Twins of Government Intelligent Street Pole Smart City as a Service Smart City Regional Governance Supply Chain Cybersecurity Water Management Analytics	Energy-Water Nexus Intelligent Connected Infrastructure Microgrids Smart City Transportation Strategy	
Moderate	Shared Mobility			
Low				

Source: Gartner (July 2023)

On the Rise

Artificial General Intelligence

Analysis By: Pieter den Hamer

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Definition:

Artificial general intelligence (AGI) is the (currently hypothetical) intelligence of a machine that can accomplish any intellectual task that a human can perform. AGI is a trait attributed to future autonomous AI agents that can achieve goals in a wide range of real or virtual environments at least as effectively as humans can. AGI is also called “strong AI.”

Why This Is Important

As AI becomes more sophisticated and powerful, with recent great advances in generative AI in particular, a growing group of people see AGI as no longer purely hypothetical. Improving our understanding of at least the concept of AGI is critical for steering and regulating AI’s further evolution. It is also important to manage realistic expectations and to avoid prematurely anthropomorphizing AI. However, should AGI become real, its impact on the economy, (geo)politics, culture and society cannot be underestimated.

Business Impact

In the short term, organizations must know that hype about AGI exists today among many stakeholders, stoking fears and unrealistic expectations about current AI’s true capabilities. This AGI anticipation is already accelerating the emergence of more AI regulations and affects people’s trust and willingness to apply AI today. In the long term, AI continues to grow in power and, with or without AGI, will increasingly impact organizations, including the advent of machine customers and autonomous business.

Drivers

- Recent great advances in applications of generative AI and the use of foundation models and large language or multimodal models drive considerable hype about AGI. These advances have been enabled largely by the massive scaling of deep learning, as well as by the availability of huge amounts of data and compute power. To further evolve AI toward AGI, however, current AI will need to be complemented by other (partially new) approaches, such as knowledge graphs, multiagent systems, simulations, evolutionary algorithms, causal AI, composite AI and likely other innovations yet unknown.
- Vendors such as Google, IBM, NNAISENSE, OpenAI and Vicarious are actively researching the field of AGI.
- Humans' innate desire to set lofty goals is also a major driver for AGI. At one point in history, humans wanted to fly by mimicking bird flight. Today, airplane travel is a reality. The inquisitiveness of the human mind, taking inspiration from nature and from itself, is not going to fizzle out.
- People's tendency to anthropomorphize nonliving entities also applies to AI-powered machines. This has been fueled by the humanlike responses of ChatGPT and similar AI, as well as AI being able to pass several higher-level education exams. In addition, more complex AI systems display behavior that has not been explicitly programmed. Among other reasons, this results from the dynamic interactions between many system components. As a result, AI is increasingly attributed with humanlike characteristics, such as understanding. Although many philosophers, neuropsychologists and other scientists consider this attribution as going too far or being highly uncertain, it has created a sense that AGI is within reach or at least is getting closer. In turn, this has triggered massive media attention, several calls for regulation to manage the risks of AGI and a great appetite to invest in AI for economic, societal and geopolitical reasons.

Obstacles

- The current issues regarding unreliability, hallucinations, lack of transparency and lack of reasoning or logic capabilities in generative AI-powered chatbots (one possible direction toward AGI), are not easy to overcome with the intrinsically probabilistic approach of deep learning. More data or more compute power for ever bigger models are unlikely to resolve these issues. Better or curated training data, improved prompt interpretation and engineering or more domain-specific foundation models may help to improve reliability, but not sufficiently.

- There is little scientific consensus about what “intelligence” and related terminology like “understanding” actually mean, let alone how AGI should be exactly defined and interpreted. Flamboyant representations of AGI in science fiction create a disconnect from reality. Scientific understanding about human intelligence is still challenged by the enormous complexity of the human brain and mind. Several breakthrough discoveries are still needed before human intelligence is properly understood at last. This in turn is foundational to the “design” or at least validation of AGI, even when AGI will emerge in a nonhuman, nonbrainlike form. Moreover, once AGI is understood and designed, further technological innovations will likely be needed to actually implement AGI. For these reasons, strong AI is unlikely to emerge in the near future. This may be sooner if one would settle for a more narrow, watered-down version of AGI in which AI is able to perform not all but only a few tasks at the same level as humans. This would no longer really be AGI as defined here.
- If AGI materializes, it is likely to lead to the emergence of autonomous actors that, in time, will be attributed with full self-learning, agency, identity and perhaps even morality. This will open up a bevy of legal rights of AI and trigger profound ethical and even religious discussions. Moreover, the (anticipated) emergence of AGI and the risk of human life being negatively impacted by AGI, from job losses to a new, AI-triggered arms race and more, may lead to a serious backlash and possibly regulatory bans on the development of AGI.
- The anticipated possible emergence of AGI urges governments to take measures before its risks can no longer be mitigated. Regulations to ban or control AGI are likely to emerge in the near future.

User Recommendations

- Today, people may be either overly concerned about future AI replacing humanity or overly excited about current AI’s capabilities and impact on business. Both cases will hamper a realistic and effective approach toward using AI today. To mitigate this risk, engage with stakeholders to address their concerns and create or maintain realistic expectations.
- Stay apprised of scientific and innovative breakthroughs that may indicate the possible emergence of AGI. Meanwhile, keep applying current AI to learn, reap its benefits and develop practices for its responsible use.
- Although AGI is not a reality now, current AI already poses significant risks regarding bias, reliability and other areas. Adopt emerging AI regulations and promote internal AI governance to manage current and emerging future risks of AI.

Sample Vendors

AGI Innovations; Google; IBM; Kimera Systems; Microsoft; New Sapience; NNAISENSE; OpenAI; Vicarious

Gartner Recommended Reading

The Future of AI: Reshaping Society

Innovation Insight for Generative AI

Innovation Insight: AI Simulation

Applying AI — Key Trends and Futures

Innovation Insight for Artificial Intelligence Foundation Models

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

Circular Supply Chain

Analysis By: Laura Rainier, Sarah Watt

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

Circular supply chain is the application of circular economy principles to the end-to-end supply chain. A circular supply chain decouples consumption from growth using three principles: design out waste, keep material in use at the highest quality for as long as possible and return materials to the environment to have a positive impact. Benefits of the circular supply chain include enhanced customer engagement, raw material security and containment of inflationary-driven costs.

Why This Is Important

A circular supply chain decouples resource consumption from growth, enabling leaders to maintain business competitiveness while reducing environmental impact. According to the 2022 Gartner Future of Supply Chain Survey, engaging in circular economy activities is important to 75% of supply chain leaders. Additionally, 92% of high-performing supply chain leaders expect to have sufficient capabilities to enable circular economy benefits in three to five years.

Business Impact

A circular supply chain uses resources more efficiently by designing waste out of products, packaging and processes, and better-leveraging materials through product take-back, refurbishment, product life extension and other means. The approach shifts economic incentives toward durability and material efficiency and provides a hedge for materials volatility. Digital technology allows for product orchestration while also gathering insights into customer use, which is fed back into product design.

Drivers

- Legislative drivers: Various regulatory requirements are emerging to drive enhanced circularity. For example, the “right to repair” requires access to spare parts and technical information to enable products to be kept in use for as long as possible. EU waste policy aims to ensure that high-quality resources are not lost from the economic system. Concerningly, 60% of EU household waste still goes to landfill.
- Supply chain resilience: Circular supply chains enable the organization to meet customer demand amid disruption through second-life products or by reclaiming raw materials for manufacturing new products.
- Impact on climate change and biodiversity: A circular approach has the potential to reduce climate change impacts, as product embodied energy (and emissions) is used more efficiently. By slowing the rate of consumption, the circular supply chain reduces its reliance on the extraction/production of new raw materials and their associated emissions. Enterprises must undertake life cycle analysis to review the environmental impacts of end-of-life options, enabling trade-off decisions to be made.
- Enhanced value: The circular economy enables enterprises to access new markets, offer new business models and products, and build a differentiated sustainability narrative.
- Innovation: The circular economy is a catalyst for innovation. Examples include design for reuse and longevity, innovative business models and design for disassembly.
- Customer expectations: According to the 2022 Gartner Circular Economy Survey, customer demand for circular products is the biggest driver of changes to the physical supply chain network to enable circular economy outcomes.

Obstacles

- Metrics: Traditional ROI metrics do not effectively capture the benefits of the circular supply chain due to short-term focus, siloed thinking and a transactional approach. Circular strategies capture more value from materials, over a longer period of time.
- Stakeholder engagement: Scaling the circular supply chain relies on engaging with partners across the organization and ecosystem. Partnership is required to enable product return flows, materials recovery, industrial symbiosis between organizations and additional customer value offerings. Convening external stakeholders and sharing relevant data with the ecosystem is a key barrier.
- Execution: Take-back models enable remanufacturing and reuse, but the supply chain has less control over what is returned. This can create excess inventory without a productive next use.
- Impact: Standards are emerging to measure the impact of circular initiatives, but accurate assessment of environmental and other trade-offs is complex.

User Recommendations

- Prioritize products: Select the products best positioned for the circular strategy by assessing which products deliver the most financial and nonfinancial benefits, evaluating the customer appetite for circular products and assessing the feasibility of circular models.
- Enable: Apply circular design guidelines (for example, modularity, durability), craft circular business models (for example, reuse, product as a service), and implement processes that enable material loops (for example, reverse logistics, reverse planning).
- Pilot: Demonstrate how to overcome common leadership concerns, such as the cannibalization of market share.
- Digitalize: Leverage digital technology for product use insights, and to improve the speed, rate and quality of second-life products. Formulate performance scorecards to aggregate data from multiple parts of the organization.
- Organize: Organization structure is a key enabler in advancing circular economy strategy. Use centers of excellence to embed circular economy into operating models.

Gartner Recommended Reading

3 Criteria to Select “Winning” Circular Economy Products to Enable Growth

3 Accelerators to Advance the Circular Economy in Supply Chain

Use Circular Economy to Mitigate Inflation, Drive Growth and Deliver Value Amid Economic Uncertainty

Craft a Reverse Supply Chain Strategy to Enable Circular Economy at Scale

How to Structure Your Organization to Drive Circular Economy Integration

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

Smart City Regional Governance

Analysis By: Bill Finnerty, Bettina Tratz-Ryan

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Definition:

Smart city regional governance implements decision making to coordinate the systems that extend across the intelligent urban ecosystem in a region, such as public safety or transportation, and may involve both public- and private-sector organizations. Regional collaboration enhances opportunities to coordinate initiatives and hold participants accountable for achieving smart city and regional community objectives that drive equity for better quality of life and decision making.

Why This Is Important

As technology evolves across regions and cities, there are a variety of socioeconomic impacts on society. Governance provides a framework for community participation in the direction of urban landscapes based on common goals that can be tracked and audited across public and private sectors. It enables scaling that supports smaller cities and rural communities participating in digital services and equity initiatives that improve quality of life for residents and visitors.

Business Impact

Businesses and local government must understand the regional governance framework and align their vision and approach with the desired impact. Operating principles and measurements must meet expectations of engagement across diverse stakeholders, leveraging data to enhance decision making and coordination of services. These actions need to be balanced with citizen trust and privacy concerns and support focused, productive dialogue across civic, government, business and constituent leadership.

Drivers

Cities are not established solely by the government, but instead include a variety of organizations such as education, healthcare, nongovernment organizations and private-sector companies that define the quality of life available to residents and visitors. Additionally, few areas are governed by a single political jurisdiction, but instead, consist of a range of municipalities and different tiers of government. Coordinating across these various partners requires a concerted effort and being driven by:

- **Opportunities for scale:** Effort to research solutions and solution providers in a buying center can benefit from being executed at a regional level, enabling communities to share expertise and buy at scale.
- **The need for accountability in regional smart city efforts:** Regional efforts that fail to establish and maintain trust among partners often struggle to achieve their mission. Smart city regional governance engenders trust across the ecosystem by building on an explicit foundation of shared goals and metrics that are discussed and developed among the partners. This provides a framework for holding each other accountable in achieving the desired intelligent urban ecosystem outcomes.
- **Regional need for smart city efforts:** Transportation, safety, environmental and economic issues do not generally begin or end at jurisdictional boundaries. Taking a regional approach is necessary to have a meaningful impact on the quality of life for all residents.
- **Examples of efforts that benefit from regional governance:** Multimodal ticketing for end-to-end smart transit; real-time crime centers that coordinate multiple agency responses; smart education initiatives to drive next-generation employment opportunities in rural communities, especially with hybrid work environments; air quality monitoring to improve health conditions for residents; homelessness response efforts that can benefit from regional data-sharing marketplaces; and equity consideration of aging population in rural areas.

Obstacles

- **Trust:** Receiving value from participating in the smart city ecosystem also requires that participants trust each other. Some have competing interests, and most have different missions.
- **Siloed Funding:** Siloed government funding can prevent cross-program and multijurisdictional use of these funds to support regional smart city efforts.
- **Value:** Perceived or actual imbalances in cost of services and value received by communities participating in regional efforts can result in mistrust among partners.
- **Sovereignty:** Concerns about political sovereignty can lead to local governments not participating in regional efforts. That can result in competing interests and priorities among jurisdictions and other potential ecosystem partners, which can make establishing common goals difficult.
- **Election Cycles:** Leadership changes in both the public and private sector can result in loss of support for regional efforts.

User Recommendations

- Improve outcomes for communities by establishing regional governance to coordinate smart infrastructure, IoT and data projects that includes a variety of stakeholders, such as regional and state/provincial government, educational institutions and the private sector.
- Design and implement the governance processes to empower decision-making efforts through the lenses of cost, value, risk and experience, and hold participating members accountable through establishing smart city KPIs.
- Establish an ecosystem model that documents the participants, rules of engagement, shared capabilities and value exchange for all involved. The defined value exchange needs to ensure that the private sector is motivated to participate and can maintain competitive advantage, the government's investments are fair and effective, and citizens benefit without undue risk or cost.

Gartner Recommended Reading

Turning Smart Cities Into Intelligent Urban Ecosystems

Smart City as a Service

Analysis By: Bettina Tratz-Ryan, Albert Gauthier

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

Smart cities as a service (SCaaS) is a model in which ecosystem partners provide smart cities with technology and data using a subscription model. Governments, nongovernment organizations and private companies are able to leverage these offerings without having to invest in infrastructure or talent to generate the related service or data, reducing entry cost and risk. The provider is able to spread the investment and risk related to establishing and maintaining the capabilities across the broader market.

Why This Is Important

Governments often face challenges related to talent, funding, security and procurement for infrastructure and technology projects. This makes it difficult to establish a strategy outlining investments to implement and maintain jurisdictionwide smart city solutions. Despite national government funding available in many countries, sustained investment in smart city solutions will be difficult. Procuring SCaaS solutions reduces risk- and cost-entry points.

Business Impact

Cities struggle to obtain the budget and expertise to build and maintain a jurisdictionwide Internet of Things (IoT) infrastructure. SCaaS enables a more agile focus on procuring services and data rather than implementing infrastructure. SCaaS requires providers to rethink their approach to smart city implementations. Direct investment in smart city infrastructure and capabilities presents new business models to maximize the data collected and services offered.

Drivers

- Governments facing financial challenges in implementing smart city infrastructure can accelerate their initiatives by becoming SCaaS consumers.
- Governments can focus on the use of data to improve outcomes without investing in the related infrastructure, thus alleviating concerns such as the talent, security and budget needed for large IoT deployments.
- Providers, particularly communications service providers deploying 5G, are seeking additional recurring revenue streams to offset costs and increase profits. Digital business models supporting new revenue by reusing multipurpose sensor packs or reselling data to multiple parties can provide reoccurring revenue.
- An increase in funding related to smart city initiatives by national and international governments — particularly related to sustainability and equity. Examples include the U.S. Infrastructure Investment and Jobs Act and The European Union NextGeneration EU.
- The growth in smart city initiatives by small and midsize cities, especially in North America.

Obstacles

- Street and light poles are not always owned by the local government. Accordingly, providers may find third parties requiring reimbursement for access to their assets instead of having a willing partner who is set to gain from implementing SCaaS.
- Many cities are considering the aesthetics of IoT sensors and developing policies to ensure that sensors and enclosures do not become a city defect.
- Nongovernment and private sector organizations may have to pay for access to data from sensors. If implemented in cities, it would be available as open data.
- Local governments that have a one-time budget but not a sustainable funding model will struggle to capitalize on a SCaaS approach.
- “As a service” models present a new approach to the smart cities market and may shy away risk-averse governments from SCaaS.
- Competing offerings may be difficult for providers to sustain in small and midsize markets, thus increasing the risk of having a single vendor option.

User Recommendations

- Engage planning and architectural review boards in developing smart city-friendly regulations to encourage private-sector investments.
- Engage providers about their roadmaps and SCaaS offerings, and adjust planning and KPIs accordingly.
- Examine public-private partnerships for SCaaS offerings to accelerate initiatives while sharing the risks and rewards with partners.
- Evaluate the risks of consuming SCaaS datasets for which vendors do not achieve anticipated market growth — as offerings may increase in price or be abandoned.
- Establish a cross-industries team to identify use cases for common smart city datasets — that is, air quality, traffic and other factors.
- Evaluate the financial and reputational risks of product portfolio planning (PPP) should the supporting markets not materialize.

Sample Vendors

Hitachi; NTT DATA; Quantela; Telus International; VALO; Zain

Supply Chain Cybersecurity

Analysis By: Brian Schultz

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Supply chain cybersecurity is a holistic and integrated approach to protecting the supply chain from operational outages, malware, ransomware, implants or other similar threats. This approach aims to protect data, IT infrastructure and cyber-physical systems used in the supply chain, as well as the products that a company manufactures and delivers. It looks internally across the organization, as well as across the third parties that make up the supply chain partner ecosystem.

Why This Is Important

Cyberattacks continue to present an ongoing, ever-evolving threat to businesses across all sectors. In 2023 we saw ransomware continue to be the most highly utilized and effective attack vector. Cyberattacks continue to have real business impacts to supply chain operations, revenue and profit. Supply chain leaders need to understand the extent of their supply chain attack surface and build a more cyber resilient supply chain.

Business Impact

Cyberattacks have brought entire supply chains to a standstill impacting operations. These attacks have resulted in significant damage to revenue, profit, reputation, brand, loss or theft of intellectual property, product safety and integrity, and substantial fines and fees.

Drivers

- Increasing automation and digitization of supply chains leads to an increased cyberattack surface.
- The increasing number of supply chain partners increases the cyberattack surface.
- Geopolitical tensions and global trade wars are increasing the likelihood and impact of cyberattacks.
- The high costs associated with operational shutdowns.
- Media visibility and awareness of cyberattacks and business impacts.
- Other roles in the supply chain becoming more aware of the threats in addition to CSCO, especially procurement, manufacturing and logistics.
- Ransomware as a service, which has made ransomware attacks more common as the technical barriers for deployment are lower. According to the 2022 Verizon Data Breach Investigations Report, “ransomware attacks surged dramatically in 2022; ransomware was involved in 25% of all breaches.” The Cybersecurity and Infrastructure Security Agency reported in February 2022 that it is aware of ransomware incidents against 14 of the 16 U.S. critical infrastructure sectors.

Obstacles

- The breadth of data and technology in need of protection within the internal supply chain and wider ecosystem.
- Lack of clarity associated with ownership and budget for management of cybersecurity risks. The pace of threat expansion makes it harder for supply chain and IT teams to keep up with the protection of systems, products and third-party deliverables.
- Lack of supply chain talent that is knowledgeable in cybersecurity.
- Fragmentation of the security tools and solutions currently available.
- Volume of upstream, downstream and IT partners that present potential third-party cyber risk to the supply chain.

User Recommendations

- Partner with CIOs and IT security and risk management leaders to develop a governance model for identifying, assessing and addressing the various cyberthreats to the supply chain.
- Assess the cyber talent needed and the required skill set for the supply chain organization.
- Map the flow of high-value supply chain data and assets across systems outside their core IT systems, including equipment in manufacturing operations or logistics networks as well as software and hardware components within products. Assess their risk and security posture.
- Conduct penetration testing exercises on your supply chain operations.
- Define security specifications with high-value supply chain partners, then pass on the specifications to supply chain partners through contract addendums.
- Implement supply chain partner assessments and continuous monitoring to identify and prioritize potential failure points and benchmark progress over time.

Gartner Recommended Reading

Supply Chain Executive Report: Combating Enterprise and Ecosystem Cybersecurity Threats

Top Trends in Strategic Supply Chain Technology 2023

Thrive in Uncertain Times by Formalizing Risk Appetite and Connecting Business and Procurement Strategies

Identify and Assess Supply Chain Risks to Improve Your Capabilities to Respond

Voice of the Customer for IT Vendor Risk Management Solutions

City Operations Center

Analysis By: Bettina Tratz-Ryan

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

A city operations center refers to a platform that helps government officials manage smart city environments with a city solution encompassing a comprehensive and holistic viewpoint. The solution delivers operational insights to optimize the city operations' efficiency and quality of citizen life through visualization. It is also referred to as command and control.

Why This Is Important

In smart city environments, speedy and seamless data exchange and information for city issues — such as traffic congestion, air pollution, energy and water consumption, safety and security conditions, and natural disasters — are required to inform different sectors and processes. This need has accelerated during the past years. It orchestrates different data sources and orchestrates user- or citizen-facing engagement including situational awareness. In many cases, it facilitates economic revenue.

Business Impact

The smart city operations center facilitates data-driven decision making which has accelerated quickly. The primary business impacts of a city operations center are to support routine operations management, resource and sustainability monitoring and optimization, automated decision making, multidimensional visualization for both macro- and micromanagement and data exchange. It will have an impact on how operational and emergency response can be executed in a timely manner, and it increases situation awareness and escalates decision making.

Drivers

- The level of adoption varies by the technical and data requirements of local governments to consolidate multiple management platforms. Very often, operations centers work together in systems approaches to align processes for emergency response, resilience, mobility management and many other objectives. To enable scale and integration, the operations center is cloud-based and linked to other platforms that may feed and exchange data and insights with it.

- In this regard, operations centers will morph from decision making into urban platforms that create an interactive engine for application development and data visualization. This will lead it to become the interface for a city digital twin, like Virtual Singapore, where city officials and ecosystem can view, develop and simulate based on the platform. In addition to control and command centers, for instance, FIWARE standards provide a framework environment that allows an urban open-source migration path for standardized service, data and process management.

- As hyperautomation progresses with GenAI and ChatGPT, there is an expectation that these platforms migrate from data orchestration and human decisions to machine based decisions that trigger contextualized automated responses.

- In a smart city strategy, different event and situational datasets are now joined from various operating management platforms and systems across government entities, districts and neighborhoods. Drivers incorporate the orchestration of massive amounts of data from IoT implementations and in-use data to extract value for operations control and city management. The delivery of KPIs for optimization of maintenance routes, asset wear and tear, and real-time decision making will be assessed in city operations centers to identify efficiency and asset instability.

Obstacles

- As there is no common standard and common framework on city operations platforms, the platforms will need to be aligned based on operating procedures and APIs. Operating platforms need data to be connected with data warehouses, data lakes or subsystems, or data fabrics, creating the IT and OT challenges of incompatible systems and different data formats and structures.
- The lack of data governance will impede the resources needed to visualize smart city impacts and services and derive real-time decisions and actions.
- There is limited financing of the operations center and limited ROI based on operational efficiency, grievance detection and fast communication on remedies.
- The procurement choices for city operations platforms range from smart city platforms, operations management or control towers which is making vendor selections and request for proposals more complex.

User Recommendations

Local government CIOs supporting smart city efforts must:

- Define the operations center as a platform for management decisions that can be leveraged across specific environments that span ecosystem objectives and partners.
- Establish data governance and management capabilities to provide solid data fusion and visualization in support of urban operations and contextualized constituent services.
- Prioritize investments in technology and data integration based on ecosystem objectives and available funding. Use a flexible approach to grow the capabilities of the city operations center.
- Work with ecosystem partners leading the implementation and management of operations centers, such as a traffic operations center or real-time crime center, to determine points of integration necessary to support collaborative response efforts. Stress-test this integration using standard operations procedures through regular exercises.

Sample Vendors

Alibaba.com; Fluentgrid; Hitachi Group; Huawei Technologies; IBM; Microsoft; NEC; NTT DATA; Picacity; Oracle

Gartner Recommended Reading

Technology Opportunity Prism: IoT in Smart Cities

Predicts 2023: Sustainable Smart City Decision Making Using Urban Data

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

Energy-Water Nexus

Analysis By: Bettina Tratz-Ryan

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

The energy-water nexus describes the complex interplay of cause and effect between water and energy supply and consumption in smart cities, industries and communities. The volatility of energy access and cost continues, and will have knock-on impacts for cost and delivery of water in the near term, accelerating some digital business investments by water utilities and governments.

Why This Is Important

The global energy cost crisis is threatening the availability of an affordable supply of water resources, placing this technology still at the peak of hype. U.N. Water Facts state that 129 countries will be off track from access to sustainably managed water resources by 2030, of which less than 10% is consumed residentially and 90% is consumed by industry and agriculture. The energy-water nexus is impacted by water availability and quality, utilization, climate change, and technology for supply or water treatment, regeneration and recycling.

Business Impact

Businesses and society cannot function without energy and water. However, competition for these resources is increasing. Stigma and reputational risks arise when business is seen to be competing with communities for these resources. Efficiency, recycling and communication of use of water helps to mitigate these risks. Reporting, transparency and communications will mitigate the concerns for depletion or water-quality risk relative to business operations.

Drivers

Climate change is accelerating water shortages, while:

- As sustainability measures, such as the United Nations Sustainable Development Group (UNSDG) or Global Reporting Initiative (GRI) frameworks, go mainstream, they are exposing industry players to reputational risk. For instance, in an energy and fuel crisis, society has to weigh oil drills against potential contamination of water sources. As an example, the fracking industry in southern U.S. is experiencing mitigation issues as it is bringing water from urban centers to the fracking locations, causing discussions about droughts and water availability in communities. In addition, fracking will increase the wastewater production and pollution of groundwater tables.
- Analytics and data generation through the Internet of Things (IoT) opens the door to insights into which processes in the generation and use of water and energy can be optimized for sustainable societal development.
- In different industries, the energy-water nexus has caused businesses to change their business processes and is challenging the sustainability of some business and operating models.
- For organizations operating in countries in which the water prices are subsidized, the use of water should be more concerned with responsible use versus scarcity, which may lead to economic penalty. Or, in a more disruptive approach, calculate the total cost of water including the entire life cycle of production and water treatment. Companies like Nestlé and Colgate Palmolive are setting their internal water prices to ensure the true price of water throughout their operations (see Why Colgate and Nestle Are Setting an Internal Price on Water, GreenBiz Group).

Obstacles

- While sustainable management of water and energy addresses sustainability and environmental risks, the absence of a true water price, without government subsidies, is hindering investment in management. Regions and countries with increasing cases of droughts and shifts in water allocation are challenged in their economic and industrial performances, especially with those regions highly dependent on oil and natural gas.
- The population growth in urban regions and rapid industrialization in developing countries are also major contributors for excessive water usage.
- At the heart of the energy-water nexus is equity, as often poor and vulnerable communities are those that are impacted first by quality, availability and pricing.
- The impact of water scarcity, and poor quality through weak regulatory enforcement, is felt in developing markets — which have limited resilience, finance and capability — to address the challenge.

User Recommendations

- Invest in water management tools that will dashboard, simulate and manage the water life cycle across operations. Include water price costing for internal water use and map the price volatility of energy in case of desalination.
- Apply technology solutions such as water forecasting systems, IoT and analytics together with modeling and simulation of energy forecasting and use.
- Perform real-time tracking of energy price volatility by analyzing data through smart city, water and energy management platforms. Identify new energy sourcing that includes waste-to-energy and circular economy principles.
- Explore the business benefit of ecosystem of microgrids, distributed grids and energy management with dispatchable pump loads that can leverage process buffers, such as storage in critical peak periods.
- Seek capabilities in water resources assessment, visibility into markets, and potentially even transaction capability in private or nontraditional water supply networks, similar to micromanaging energy.

Sample Vendors

ABB; ADASA; Black & Veatch; Deloitte; Fujitsu Group; Hitachi Group; Schneider Electric; SUEZ

Gartner Recommended Reading

Tool: AI Use Cases for Smart Cities and Intelligent Urban Ecosystems

2023 Utility Trend: Water Security Management Is the Water Industry's Existential Imperative

Quick Answer: How to Meet a Net Positive Water Commitment

Greenfield Smart City Framework

Analysis By: Bettina Tratz-Ryan

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Definition:

A "greenfield" smart city framework is a strategic plan using net-zero principles and emerging technology (such as metaverse and autonomous operations and experiences) to develop a new urban area or district with limited or no existing infrastructure, such as communications, electrification and resource supply, into a sustainable ecosystem. All government and industry sectors link to community, district and industry collaboration platforms through IT, AI and digitalization.

Why This Is Important

Greenfield smart cities are increasingly gaining attention from conglomerates of urban real estate developers and governments in emerging countries that want to create digital, sustainable and intelligent smart city projects. These greenfield programs require a holistic framework that connects national, business and societal goals with urban or regional development, often built on a city operations center that shares information across the ecosystem looking to benchmark performance.

Business Impact

Adoption is slow, as the business of building an ecosystem to configure a greenfield smart city framework is immense. Interoperability is needed between data exchanges, technology platforms and the Internet of Things (IoT). Real estate developers of greenfield smart cities seek to develop self-sufficient and environmental knowledge centers, and to implement operations to curb inefficiencies in the infrastructure and through citizen communications and service platforms.

Drivers

- Adoption is evident in examples such as India's announcement that smart cities will be the core of urban, industrial and social development. NEOM, Toyota Woven City and Chicago's Lincoln Yards are examples of new housing districts or even entire cities being built from the ground up through public and private ecosystems. Climate adaptation also drives smart city development — as Jakarta sinks, Indonesia is building a new capital, which will be called Nusantara, on Borneo.
- Standardization of greenfield services will come from an urban control center sharing information and business models across the ecosystem and looking to benchmark KPIs on performance and delivery.
- Many investments will depend on reaching the goals of institutional investors like the World Bank Group, which will provide governance in these projects.
- Business leaders determine the ownership of implementing vision and methodology and develop easy-to-use profitable business services. These services will be available through smart city application stores or city marketplaces.
- Governance will be required by institutions like the World Bank to create transparency in the investment process, as well as in the U.N.'s sustainable development goals. In addition, many emerging cities are eligible for the COP21 climate change funds when their infrastructure is delivered due to climate change considerations.
- From an ecosystem perspective, the thrust toward digitalization across industry, business and society can be channeled in greenfield districts as innovation districts or corridors. This can include sensors, autonomous assets and mobility, data-driven service models or new green tech development. This requires leaders to build a holistic, secure and scalable infrastructure foundation to enable capacity-intensive use cases and applications.

Obstacles

- The complexity of master planning often faces issues between being a political showdown with innovation and tech at the center and building a community with demographic diversity at the heart.
- City governments have neither experience nor knowledge on how to design, construct and operate the smart city, and often rely on urban architects.
- Technology and infrastructure experts often prioritize roll out of infrastructure, while data-driven platforms deliver district and urban services. These must come to an agreement on which urban objectives should go first.
- Many greenfield environments will derive value for commercial ecosystems through widespread access to users' and citizens' data. Data privacy issues need to be considered and well-communicated — failure to do so will lead to mixed adoption and low citizen approval.

User Recommendations

- Build digital business models for greenfield smart cities, leveraging lessons from the industrial ecosystems that have built transaction or collaboration platforms. Focus on best practices for process and data exchange, including financial and risk-sharing models.
- Design citizen experiences around work-life balance, digital work, citizen entrepreneurship, culture, traditional lifestyle or sustainable living, because you need citizens' buy-in for data exchanges across the variety of ecosystem participants delivering the experience and outcome. Otherwise, you may get entangled in privacy discussions.
- Ensure flexibility when implementing the project to cope with changes. The development of a greenfield framework will take considerable effort. The ability to report financing and investment strategies to banks and investors is critical to validate the KPIs of the smart city solutions to be deployed.

Sample Vendors

Accenture; Arup; Atos; Capgemini; Cisco Systems; Fujitsu; Hitachi; IBM; NTT DATA; Picacity

Gartner Recommended Reading

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

Edge AI

Analysis By: Eric Goodness

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Adolescent

Definition:

Edge AI refers to the use of AI techniques embedded in non-IT products, IoT endpoints, gateways and edge servers. It spans use cases for consumer, commercial and industrial applications, such as autonomous vehicles, enhanced capabilities of medical diagnostics and streaming video analytics. While predominantly focused on AI inference, more sophisticated systems may include a local training capability to provide optimization of the AI models at the edge.

Why This Is Important

Many edge computing use cases are latency-sensitive and data-intensive, and require an increasing amount of autonomy for local decision making. This creates a need for AI-based applications in a wide range of edge computing and endpoint solutions. Examples include real-time analysis of edge data for predictive maintenance and industrial control, inferences and decision support where connectivity is unreliable, or video analytics for real-time interpretation of video.

Business Impact

The business benefits of deploying edge AI include:

- Real-time data analysis and decision intelligence
- Improved operational efficiency, such as manufacturing visual inspection systems that identify defects, wasted motion, waiting, and over- or underproduction
- Enhanced customer experience, through feedback from AI embedded within products
- Connectivity cost reduction, with less data traffic between the edge and the cloud
- Persistent functions and solution availability, irrespective of network connectivity

- Reduced storage demand, as only prioritized data is passed on to core systems
- Preserved data privacy at the endpoint

Drivers

Overall, edge AI has benefited from improvements in the capabilities of AI. This includes:

- The maturation of machine learning operationalization (MLOps) and ModelOps tools and processes support ease of use across a broader set of features that span the broader MLOps functions. Initially, many companies came to market with a narrowcast focus on model compression.
- The improved performance of combined ML techniques and an associated increase in data availability (such as time-series data from industrial assets).

Business demand for new and improved outcomes solely achievable from the use of AI at the edge, which include:

- Reducing full-time equivalents with vision-based solutions used for surveillance or inspections.
- Improving manufacturing production quality by automating various processes.
- Optimizing operational processes across industries.
- New approaches to customer experience, such as personalization on mobile devices or changes in retail from edge-based smart check-out points of sale.

Additional drivers include:

- **Increasing number of users upgrading legacy systems and infrastructure in "brownfield" environments.** By using MLOps platforms, AI software can be hosted within an edge computer or a gateway (aggregation point) or embedded within a product with the requisite compute resources. An example of this is AI software deployed (TinyML) deployed to automotive or agricultural equipment to enhance asset monitoring and maintenance.

- **More manufacturers embedding AI in the endpoint as an element of product servitization.** In this architecture, the IoT endpoints, such as in automobiles, home appliances or commercial building infrastructure, are capable of running AI models to interpret data captured by the endpoint and drive some of the endpoints' functions. In this case, the AI is trained and updated on a central system and deployed to the IoT endpoint. Examples of the use of embedded (edge) AI are medical wearables, automated guided vehicles and other robotic products that possess some levels of intelligence and autonomy.
- **Rising demand for R&D in training decentralized AI models at the edge for adaptive AI.** These emerging solutions are driven by explicit needs such as privacy preservation or the requirement for machines and processes to run in disconnected (from the cloud) scenarios. Such models enable faster response to changes in the environment, and provide benefits in use cases such as responding to a rapidly evolving threat landscape in security operations.

Obstacles

- Edge AI is constrained by the application and design limitations of the equipment deployed; this includes form factor, power budget, data volume, decision latency, location and security requirements.
- Systems deploying AI techniques can be nondeterministic. This will impact applicability in certain use cases, especially where safety and security requirements are important.
- The autonomy of edge AI-enabled solutions, built on some ML and deep learning techniques, often presents questions of trust, especially where the inferences are not readily interpretable or explainable. As adaptive AI solutions increase, these issues will increase if initially identical models deployed to equivalent endpoints subsequently begin to evolve diverging behaviors.
- The lack of quality and sufficient data for training is a universal challenge across AI usage.
- Deep learning in neural networks is a compute-intensive task, often requiring the use of high-performance chips with corresponding high-power budgets. This can limit deployment locations, especially where small form factors and lower-power requirements are paramount.

User Recommendations

- Determine whether the use of edge AI provides adequate cost-benefit improvements, or whether traditional centralized data analytics and AI methodologies are adequate and scalable.
- Evaluate when to consider AI at the edge versus a centralized solution. Good candidates for edge AI are applications that have high communications costs, are sensitive to latency, require real-time responses or ingest high volumes of data at the edge.
- Assess the different technologies available to support edge AI and the viability of the vendors offering them. Many potential vendors are startups that may have interesting products but limited support capabilities.
- Use edge gateways and servers as the aggregation and filtering points to perform most of the edge AI and analytics functions. Make an exception for compute-intensive endpoints, where AI-based analytics can be performed on the devices themselves.

Sample Vendors

Akira AI; Edge Impulse; Falkonry; Imagimob; Litmus; MicroAI; Modzy; Octonion Group; Palantir

Gartner Recommended Reading

Building a Digital Future: Emergent AI Trends

Emerging Technologies: Neuromorphic Computing Impacts Artificial Intelligence Solutions

Emerging Technologies: Edge Technologies Offer Strong Area of Opportunity — Adopter Survey Findings

Emerging Tech Impact Radar: Edge AI

Urban Sustainability and COP 26

Analysis By: Bettina Tratz-Ryan

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

Cities are becoming environmental and sustainability centers of excellence due to commitments made to the U.N. Framework Convention on Climate Change in 2021 (COP 26), as well as the U.N. Sustainable Development Goals (SDGs). Almost 1,000 cities that made this commitment are focusing on climate change risk management and opportunity identification. Urban sustainability is using measurements like ISO 37120 to measure impacts and delivery on climate resilience while protecting citizens.

Why This Is Important

Cities face issues of rising sea levels, rising temperatures and biodiversity loss, as well as multiple adverse environmental threats. The pandemic's aftermath has exposed social issues, including inequality of social sustainability, for instance, in mobility or housing. Many local governments are addressing these issues with "resilience strategies" to rebuild infrastructure, support sustainable industries and ensure holistic citizen engagement through a focus on SDGs.

Business Impact

Cities will demand more sustainable services and transparency. COP 21 was the launchpad for COP 26 declarations by city leaders/nonstate parties on digital sustainability goals. CIOs can innovate by linking technology projects to green initiatives. Data becomes instrumental for policy decision making, and CIOs can develop architectures and shared infrastructure that balance services with related greenhouse gas (GHG) emissions and a wider, circular environmental impact from IT.

Drivers

- The European Green Deal is making carbon emission reductions and circular economy key enablers for sustainable living. The diversity of political and demographic environments will, however, change the momentum for local governments due to inflation, funding and economic discussions. The polarization between citizens, government and urban ecosystem is driving the hype, and it is moving this technology faster through the Peak of Inflated Expectations.
- The momentum and adoption rate are driven by citizen, business and investor concerns about climate change. For example, the lack of or slow response to addressing climate change in cities has led to heat islands in cities, exposing vulnerable citizens and requiring a redesign of spatial planning and urban site development. Using rooftops for solar energy supports the renewable energy strategy of cities. Interest groups, such as C40 for cities and European Green Capital share insights on carbon reduction, sustainability initiatives and key performance indicators (KPIs) to measure impact.
- Based on some local impacts and the social cohesion and contextualization of the urban service environment generated through projects that address cities' distinctive needs, cities will outpace countries and regions in sustainability and environmental momentum and execution.

Obstacles

- Climate crisis in cities is a result of climate change, loss of biodiversity, pollution and inefficient resource use. An intelligent urban ecosystem can manage sustainability impacts with good data on primary and secondary material impacts on the city and citizens. Datasets are rarely available in scale from the industry and need to be standardized on public platforms, especially for Scope 3 GHG, pollution or social sustainability.
- Data sharing needs to include GHG emission data so industry partners (e.g., insurance, real estate development, banking, and logistics and supply chain) can model their impacts to avoid a business risk and data security concerns.
- Reaching sustainability goals needs to be more transparent, granting CIOs options for frameworks such as STAR Communities and World Bank Group's CityStrength D iagnostic to orchestrate data.
- Meeting sustainability goals will likely require businesses and government leaders to make difficult short-term decisions that require political will.

User Recommendations

- Define the KPIs of smart city initiatives in sustainability terms. Create advisories on usage of Internet of Things by citizen advisory boards for measuring emissions, air pollution, waste and recycling rates.
- Using a materiality understanding for sustainability impacts, apply technology to assess operational efficiency, data sharing and business process alignment to condense the urban asset footprint, while visualizing this impact in various channels. Support developing collaboration and dashboarding of sustainability-minded citizens who will engage in environmental activities, such as restricting high-emission vehicles in city centers and offering energy conservation and green energy options for streetlights and buildings.
- Cooperate in public-private partnerships with utilities, waste management companies and consumer goods providers to create business awareness and end-to-end, circular, city life cycle applications in microgrids, recycling, and smart building and home ecosystems.

Sample Vendors

CDP; Cowlines; Deloitte; E.ON; Esri; Libelium; Nesting; QCumber; Sphera; Urbaser

Gartner Recommended Reading

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

Predicts 2023: Sustainable Smart City Decision Making Using Urban Data

Civic and Community Development

Analysis By: Bettina Tratz-Ryan

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

Civic and community development in smart cities aims to support the social and community issues identified in a social cohesion strategy. Platforms and applications are used to develop a collaboration mechanism to engage stakeholders through actively establishing an open dialogue between societal and demographic parties. Citizens are being consulted on policies, community issues and digitalization efforts.

Why This Is Important

Civic and community engagement is accelerating through the availability of open data, as well as location- and sentiment-related data to assess citizen sentiment through information exchange or behavioral analytics in an anonymized way. The pandemic has unearthed a social divide across citizens, especially on issues like good access to education, quality of life, health and good infrastructure. Cities are actively pursuing a variety of digital engagement models to reach the entire community with services.

Business Impact

The business impact of civic and community development aligns a contextualized communications approach with dedicated applications for different demographics. Many of the industrial engagement platforms, including communities on consumer applications such as Facebook and Google, show that community identification significantly increases the satisfaction rate with surroundings — that is, city or urban management. It will also provide inclusion as it is connecting citizens to quality of life.

Drivers

- The speed of adoption of civic and community engagement and development has increased due to the differentiated demographic needs related to postpandemic social requirements. With pandemics and other direct life-changing events, disadvantages through the digital divide have been highlighted globally at different scales. This demographic and social inclusion trend includes older generations, migrants and millennials in community participatory research. It will apply different use patterns of communications and engagement technologies, and their impact on the city environment.
- Diverse citizen requirements are driving cities to build citizen engagement and civic outreach through special departments, but will also be using NGOs to engage with citizens consistently as trusted partners in the community, to bridge translation and understanding issues. Those NGOs have been working as conduits in many cities to facilitate connections between city police and teenagers; for instance, something that can be also supported through a broad civic environment.
- Cities will focus on data trust or literacy of citizens. Data trust will cater to sentiments and citizen issues, and citizen engagement will address issues of "social cohesion," which is defined as the ability of a community to create an equal, safe and prosperous community.
- Consumerization of digital technology, as well as ease of use of social platforms, smartphones, e-commerce and analytics will lower the barriers for citizens to interact and transact with one another for community development. Those engagements are developing from the bottom up, leading to participatory engagement by, for instance, linking citizen science to environmental health.
- The increasing social fracture in the community is accelerating political debates on digital equity and inclusion, and civic and community development platforms are driving the visualization of mitigation efforts.

Obstacles

- The acceleration of civic and community engagement frameworks, platforms and applications depends on citizens and communities trusting government activities. Community development is sustainable when communities feel empowered to advance not only on various issues, but also on personal perseverance.
- The level of adoption varies based on regional or communal governance on data privacy and security. This includes GPS and user-centric data collected through IoT, as well as more formalized citizen ID, or e-ID engagements, with General Data Protection Regulation (GDPR).
- The lack of digital literacy and equity is slowing the adoption of digital civic and community engagement tools, or the access to those.

User Recommendations

- Moderate constituents and public and private entities on the use of data and technology by applying an information hub or platform for citizen developers and community NGOs. CIOs could apply augmented reality, AI and chatbots to build native language suggestions to lower the barrier of engagement by offering frictionless user interfaces.
- Use gamification and collaboration tools to crowdsource citizen sentiment through social media engagement. For example, position hackathons to allow civic groups to be involved in innovation projects.
- Prioritize inclusion in community, labor markets, environment, education and health. Inclusion needs to be provided with single identity management that will create trust in data sharing, and will improve quality of life in obtaining more comprehensive services.

Sample Vendors

CitizenLab; Esri; Indra (Minsait); Tableau

Gartner Recommended Reading

Competitive Landscape: Community Development and Regulation Applications, U.S. State and Local Government

Top Trend in Public Safety and Justice: Digital Community Collaboration

Data Exchange

Analysis By: Bettina Tratz-Ryan

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Definition:

Data exchanges in intelligent urban ecosystems contextualize the sharing of data between smart city stakeholders and the industry for public value and societal benefit. The concept was developed from the architecture of commercial data marketplaces. The context and significance of developing and executing on valuable data streams for various public and private use cases drives the value of data.

Why This Is Important

In an intelligent urban ecosystem/smart city, data access and its exchange are important for orchestrating data streams from multiple sources and connecting them with ecosystem stakeholders. The acceleration of data exchanges used by industry and government sectors is triggered by financial or shared outcome terms based on various transaction mechanisms. This will establish a “system of systems” approach that potentially offers data exchange as a service.

Business Impact

Leveraging usable and impactful data from the data exchange leads to an increased public data trust and societal benefits through transparency to use the same information insight and dataset. For example, smart campuses, industry parks and downtown areas develop mobility, service enhancements for carbon emissions, concierge or health benefits, and retail and office services by accessing data exchanges. Data exchanges create an innovation thrust for new digital business models by cross-referencing the environment.

Drivers

- By associating the right data with people or situations, city managers can provide responsive services that apply predictive and contextualized capabilities to anticipate unfolding events in real time.
- The exchange of business or industry datasets, together with prioritization on quality of assessments for modeling or real-time decision making, becomes a critical enabler of service quality for the entire urban ecosystem.
- The speed of adoption has been changed to five years, given that many cities are building out data orchestration using data generated by government agencies, citizens, assets and businesses as well as operations management data resulting from urban infrastructure and operations.
- With insight-related and data-driven interactions between public and private sectors, cities and smart communities have opportunities to create service and market response agility by identifying market data for digital knowledge sharing and management, including crowdsourcing insights that could support communities to develop civic entrepreneurship.
- Organizations in utilities, automotive, real estate or retail are showing interest in ecosystem data in smart districts to leverage curbside or data exchange data for new service models. That can lead to data monetization acceleration.
- Sustainability-data-related data exchanges — for instance for carbon emissions, energy efficiency, heat islands in cities or circular economy — have started to take place.
- The data exchanges in China allow for fast data analytics and monetization, leading to new citizen data innovation. Especially with generative AI and rapid embedded data analytics, global data exchanges will feel pressure to develop a data exchange strategy that is inclusive of stakeholders to avoid regulation.

Obstacles

- Data literacy is a critical enabler for data exchanges because it helps to create skills in using data for all business activities, inadvertently turning to empowerment and trust in the data exchange mechanism. Without literacy and trust, the ecosystem will be challenged to tap into good data for business development, especially in relation to privacy grounds.
- The value and market price of enriched data can be determined by the business opportunity represented and on the certifiable quality of the data itself to cities and the wider industrial ecosystem. Its adoption rate will vary based on the ability to convince the data owners of data orchestration and sharing's value. It also requires the technical interoperability of data layers and analytics systems.
- The ability to contextualize data within data orchestration requires data collection and dissemination based on a city's understanding and skills of industrial data governance, which need to be applied throughout the ecosystem.

User Recommendations

- Examine standardization or adaptive governance models to feed open-source application and delivery models as they plan to integrate their application operation systems and platforms. The ability to interface with middleware underlying a proposed ecosystem will be critical.
- Mitigate the ecosystem's scalability issues by engaging with third-party developers or other entities to enable solutions in automotive, environmental development and journey mapping.
- Engage in discussions with the business and knowledge communities and collaborate with them on identifying/prioritizing use cases, ethical digital rights management, data attributes required and privacy/security issues. In the long term, develop a roadmap for connecting a "system of data marts" that embeds open data portals and warehouses in an algorithmic business environment.
- Appraise chatbots and smart machines for creating automatic and machine learning to facilitate democratized data-driven insights to people who are not data scientists.

Sample Vendors

Cloudera; Dawex; HERE Technologies; Hitachi; IBM; Insait; NTT DATA; Opendatasoft; Picacity

Gartner Recommended Reading

From Smart City to Intelligent Urban Ecosystem — Unlocking Data Value Is the Key to Cities' Industrial Partnerships

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

Edge Computing

Analysis By: Bob Gill, Philip Dawson

Benefit Rating: Transformational

Market Penetration: More than 50% of target audience

Maturity: Early mainstream

Definition:

Edge computing describes a distributed computing topology in which data storage and processing are placed in optimal locations relative to the location of data creation and use. Edge computing locates data and workloads to optimize for latency, bandwidth, autonomy and regulatory/security considerations. Edge-computing locations extend along a continuum between the absolute edge, where physical sensors and digital systems converge, to the “core,” usually the cloud or a centralized data center.

Why This Is Important

Edge computing has quickly become the decentralized complement to the largely centralized implementation of hyperscale public cloud. Edge computing solves many pressing issues, such as sovereignty, unacceptable latency and bandwidth requirements, given the massive increase in data produced at the edge. The edge-computing topology enables the specifics of Internet of Things (IoT), digital business and managed distributed IT solutions.

Business Impact

Edge computing improves efficiency, cost control, and security and resilience through processing closer to where the data is generated or acted upon, fostering business opportunities and growth (e.g., customer experience and new real-time business interactions). Earliest implementations succeeded in enterprises that rely on operational technology (OT) systems and data outside core IT, such as the retail and industrial sectors.

Drivers

- Growth of hyperscale cloud adoption has exposed the limits of extreme centralization. Latency, bandwidth requirements, the need for autonomy and data sovereignty or location requirements may be optimized by placing workloads and data closer to the edge, rather than centralizing in a hyperscale data center.
- Data growth from interactive applications and systems at the edge often cannot be economically funneled into the cloud.
- Applications supporting customer engagement and analysis favor local processing for speed and autonomy.
- IoT is evolving from simply reporting device status to using edge-located intelligence to act upon such status, bringing the benefits of automation and the creation of immediately responsive closed loop systems.
- Edge computing's inherent decoupling of application front ends and back ends provides a perfect means of fostering innovation and enhanced ways to do business. For example, using technologies such as machine learning and industrial sensors to perform new tasks at locations where business and operational events take place, or at the point of interaction with a retail customer, can drive significant business value.

Obstacles

- The diversity of devices, software controls and application types all amplify complexity issues.
- Widespread edge topology and explicit application and networking architectures for edge computing are not yet common outside vertical applications, such as retail and manufacturing.
- Edge success in industrial IoT applications and enhancing customer experience in retail are well-understood, but many enterprises still have difficulty understanding the benefits, use cases and ROI of edge computing.
- A lack of broadly accepted standards slows development and deployment time, creating lock-in concern for many enterprise users.
- Edge physical infrastructure is mature, but distributed application management and orchestration challenges are still beyond most vendor-supplied component management offerings. The tasks of securing, maintaining and updating the physical infrastructure, software and data require improvement before management and orchestration can mature.

User Recommendations

IT leaders responsible for cloud and edge infrastructure should:

- Create and follow an enterprise edge strategy by focusing first on business benefit and holistic systems, not simply focusing on technical solutions or products.
- Position edge computing as an ongoing, enterprisewide journey toward distributed computing, not simply individual isolated projects.
- Establish a modular, extensible edge architecture through the use of emerging edge frameworks and design sets.
- Accelerate time to benefit and derisk technical decisions through the use of vertically aligned systems integrators and independent software vendors that can implement and manage the full orchestration stack from top to bottom.
- Evaluate “edge-as-a-service” deployment options, which deliver business-outcome-based solutions that adhere to specific SLAs while shifting deployment, complexity and obsolescence risk to the provider.

Gartner Recommended Reading

Market Guide for Edge Computing

5 Top Practices of Successful Edge Computing Implementers

Sliding into the Trough

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

5G

Analysis By: Sylvain Fabre

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early 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 ultra reliable 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 supports the 4th industrial revolution and IoT. Its fast and reliable real-time data transfer will benefit many industries. 5G supports eMBB, URLLC and MIoT — vital for enterprise transformation. 3GPP 5G standards releases deliver incremental functionality in: R15, extreme mobile broadband; R16, industrial IoT (massive IoT, slicing and security) — latest commercially available release; R17, MIMO enhancements, sidelink, DSS, IIoT/URLLC, bands up to 71GHz, nonterrestrial networks; and RedCap R18 is under definition with a planned freeze date in 1Q24.

Business Impact

- 5G enables three main technology deployments; each supports distinct new services for multiple industries and use cases of digital transformation, and possibly new business models (such as latency as a service). These are enhanced mobile broadband (eMBB) for HD video, mMTC for large IoT deployments, and URLLC for high-availability and very low-latency use cases, such as remote vehicle operations.
- Promising applications for 5G use include fixed wireless access, IoT support and private mobile networks.

Drivers

- Over 249 operators have rolled out 5G (see GSA), 30% of public mobile networks, and some form of 5G capability is penetrating lower cost smartphones in vendors' portfolios (with over nine versions of the technology depending on the band and the 3GPP release).
- Gartner estimates that 5G-capable handset penetration in 2025 will reach 54% worldwide, and 78% in Western Europe, with 5G-capable handset share of sales reaching 80% in 2023 in Western Europe from 51% in 2021. North America share will rise to close to 87%.
- 5G capability is starting to deliver value in emerging always-on wearables use cases.
- Increased data usage per user and device requires a more efficient infrastructure.
- Requirements from industrial users value 5G lower latency from ultra reliable and low-latency communications (URLLC) and expect 5G to outperform rivals in this area.
- Demand continues for massive machine-type communications (mMTC) to support scenarios of very dense deployments up to the 5G target of one million connected sensors per square kilometer. While diverse networks can offer adequate and cost-effective alternatives to 5G for many use cases (e.g., LPWA, NB-IoT, LoRa, Wi-SUN), overall total cost of ownership (TCO) and future proofness may not be as good.
- Availability has increased for industry-specific spectrum options (e.g., CBRS).
- Competitive pressures continue, for example, if one CSP launches 5G in the market others usually have to follow or risk losing market share — this includes both public as well as private 5G offerings.

Obstacles

- Issues with availability and cost of spectrum, in particular for industrial private networks, occur in some countries.
- Security concerns arise when using 5G in critical industrial scenarios.
- Availability and pricing of networks and modules for R16 and beyond solutions.
- Upgrade to 5G SA (stand-alone) core is needed for more advanced R16 releases (such as slicing), and commit to the continuous evolution of 5G releases over R17, R18 and beyond.
- Cost of radio network upgrades for 5G coverage and availability may require additional sites.
- Use of higher frequencies and massive capacity requires denser deployments with higher frequency reuse, which could raise network costs.
- Uncertainty exists about use cases and business models that may drive 5G for many CSPs, enterprises, and technology and service providers (TSPs).
- Feedback from some industrial clients mentioned that the majority of their use cases could be serviced by a 4G private network, Wi-Fi and/or NB-IoT, and other LPWA such as LoRa.

User Recommendations

- Enable R16 and above 5G for enterprise connectivity for mobile, nomadic and FWA secondary/tertiary use cases for branch location redundancy, as long as 5G is not the primary link for high-volume or mission-critical sites and unless there are no other options.
- Provide clear SLAs for network performance by testing installation quality for sufficient and consistent signal strength, signal-to-noise ratio, video experience, throughput and coverage for branch locations.
- Ensure backward compatibility to 4G devices and networks, so 5G devices can fall back to 4G infrastructure.
- Focus on architecture readiness — such as SDN, NFV, CSP edge computing and distributed cloud architectures, and end-to-end security — in preparation for 5G.
- Build an ecosystem of partners to target industry verticals more effectively with 5G before your competition.

Sample Vendors

Ericsson; Huawei; Mavenir; Nokia; Qualcomm; Rakuten Symphony; Samsung Electronics; ZTE

Gartner Recommended Reading

Emerging Tech: 5G mmWave at a Crossroads

Infographic: 5 Steps for Vendors to Scope and Run Successful POCs for Enterprise 5G PMNs

Invest Implications: Magic Quadrant for 5G Network Infrastructure for Communications Service Providers

Market Guide for 4G and 5G Private Mobile Networks

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

Digital Ethics

Analysis By: Pieter den Hamer, Frank Buytendijk, Svetlana Sicular, Bart Willemsen

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Digital ethics comprises the systems of values and moral principles for the conduct of electronic interactions among people, organizations and things. It applies to areas such as AI, data and analytics, and social media.

Why This Is Important

Digital ethics, especially around topics like privacy, bias, polarization and veracity, is a concern to many. The voice of society is getting louder, with responsible AI coming into sharp focus for individuals, organizations and governments. People, increasingly aware that their data is valuable, are frustrated by lack of transparency, misuse and breaches. Organizations are acting to mitigate ethical risks around data, AI and other digital areas, while more governments are encouraging and regulating responsible use of these in digital society.

Business Impact

Digital ethics strengthens an organization's positive influence and reputation among customers, employees, partners and society. Areas of business impact include innovation, product development, customer engagement, corporate strategy and go-to-market. Intention is key. If ethics is simply a way to achieve business performance, it comes across as disingenuous. The goal to be an ethical organization serves all parties and society more broadly, and leads to better business trust and performance.

Drivers

- The media is frequently featuring high-profile stories about the impact of data, AI and other technology on business and society at large. Board members and other executives are increasingly sharing concerns about the unintended consequences of innovative technology use.
- For many technologies, ethics was often an afterthought. However, with the emergence of artificial intelligence, the ethical discussion is now taking place both before and during a technology's widespread implementation. AI ethics aims to establish responsible use of AI and to harness AI's growing powers.
- The current hype around generative AI, including ChatGPT and similar alternatives, is raising awareness about ethical and legal issues surrounding the veracity and (intellectual) ownership of data, including training data. In addition, the potential impact of inaccurate, misleading or insensitive output is fueling ethical concerns.
- Government commissions and industry consortia are actively developing guidelines for ethical use of AI. Examples include the EU's AI Act, the Netherlands' Fundamental Rights and Algorithm Impact Assessment (FRAIA), and the U.S.'s National AI Research Resource (NAIRR) Task Force and National Artificial Intelligence Initiative to advance trustworthy AI in the U.S.
- Over the past few years, a growing number of organizations declared their AI ethics principles, frameworks and guidelines. Many are in the process of going from declaration to execution.
- Universities across the globe have added digital ethics courses and have launched programs to address ethical, policy and legal challenges posed by new technologies.
- Digital ethics is expanding to address concerns about rising energy consumption. In the case of nonrenewable energy, it is focusing on the carbon footprint of digital technology (particularly, machine learning and blockchain).

Obstacles

- Because of the ambiguous, pluralist and contextual nature of digital ethics, organizations often struggle to operationalize it and expend significant effort to implement best practices.
- Organizations see digital ethics as a moving target because of confusion around society's expectations. An organization's position and beliefs may even steer digital ethics against the majority's opinion.
- Digital ethics is too often reactive, narrowly interpreted as compliance, reduced to a checklist, confined to technical support for privacy protection, and/or viewed only as explainable AI.
- AI ethics is currently the main focus of digital ethics. Supporting technology (e.g., to protect privacy or mitigate bias) needs to mature further and apply to the broader scope of ecosystems rather than singular technologies.
- Across people, regions and cultures, opinions differ on what constitutes "good" and "bad" and what doing the right thing means. Even in organizations that recognize ethics as an important issue, consensus between internal and external stakeholders (such as customers) is sometimes illusive.

User Recommendations

- Identify specific digital ethics issues and opportunities to turn awareness into action.
- Discuss ethical dilemmas from diverse points of moral reasoning. Anticipate and account for ethical consequences. Ensure that you are comfortable defending the use of a technology, including any unintended negative outcomes.
- Elevate the conversation by focusing on digital ethics as a source of societal and business value, rather than simply focusing on compliance and risk. Link digital ethics to concrete business performance metrics.
- Ensure that digital ethics is leading and not following the adoption of new, transformative technology such as AI. Address digital ethics upfront "by design" to create methods that identify and resolve ethical dilemmas as early as possible.
- Organize training in ethics, and run workshops to create ethical awareness within all AI initiatives. These should emphasize the importance of an ethical mindset and clear accountability in AI design and implementation.

Gartner Recommended Reading

Tool: Assess How You Are Doing With Your Digital Ethics

Tool: How to Build a Digital Ethics Curriculum

AI Ethics: Use 5 Common Guidelines as Your Starting Point

How to Manage Digital Ethical Dilemmas

How to Operationalize Digital Ethics in Your Organization

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

Smart City Framework

Analysis By: Bettina Tratz-Ryan

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Definition:

A smart city framework guides urban development toward a data exchange of an intelligent urban ecosystem. This will improve citizens' lives, stimulate the economy and protect the environment. The ecosystem of actors is facilitated with data marketplaces, algorithmic business, legal frameworks and policies. They define and measure the impact of technology through data and analytics to create a user-focused and contextualized experience.

Why This Is Important

Many intelligent urban ecosystems and cities accelerate the development of a smart city framework based on social development, sustainability, economic recovery and safety issues, rather than solely on technology they could invest in. Local governments are now including data exchanges to generate data sharing-enabled ecosystems that build digital business services and experiences for customers and citizens.

Business Impact

The business impact of smart city frameworks is driven by the ability to automate and deliver better service experiences through data exchange and data trust. Open data portals and data marketplaces will provide transformational access to an urban context that will be used to drive more use cases and user-specific ambient services, including demographic changes, digital skills, knowledge exchange and sustainability-related ambience.

Drivers

- The digitalization of daily life and urban operations, especially with the increasing flow of data, is driving the architecting of a city framework that will keep the level of embedded application on an equitable level with citizen trust and benefit. It will allow decision makers to develop a vision with guardrails that neither stifle innovation nor expose the community to perceived intrusive technology choices.
- Governance and engagement structures will be established by local governments that will manage and support the interactions and create a winning formula between city, economy and society.
- Contextualized data will come from preferences and movement data of residential and business users that map to real-time data from infrastructure and services.
- The smart city framework will be empowered through technology approaches such as cloud and big data management. As cities work together as regions, a holistic platform approach with a system of systems is being developed that allows interoperability and data governance of new services, including city algorithms as a service.
- Sustainability- and climate-change-related issues are becoming an increasingly litmus test for cities, as they need to follow net zero carbon emission timelines for infrastructure, traffic and operations. Biodiversity in spatial planning, near zoning green spaces and recreation, as well as the health aspects that it creates for people, will be factors for environmental implementations that are socially balanced and do not burden society.

Obstacles

- Blending data will add to privacy and safety discussions in specific use cases across the ecosystem, including local government.
- With increasing data analytics and AI utilization, the challenge of the perception of security and bias in storage and management of data is increasing, and the framework needs governance. Therefore, digital equity, data laws and AI ethics need to be included, leading toward a data vault and trust factors. Digital needs to be aligned with social equity, including service equity, which is often aligned with decision makers outside of smart city or digitalization initiatives.
- Building a framework requires all stakeholders to agree on a common set of goals. This includes not only the definition of urban development, but also the holistic social, demographic and economic objectives as embedded in a sustainable smart city environment. Articulating the outcome and benefits often hinges on political, financial or short-term priorities, rather than long-term vision.

User Recommendations

- Operate and manage the city perception of residential and business constituents as depicted in the framework by developing a data-driven decision roadmap.
- Develop guidelines and a governance mechanism for data trust, ethical AI and data privacy issues.
- Share insights and data orchestration with other smaller cities or regional partners by developing a synchronized network of best practices for cities, avoiding the duplication of infrastructure, Internet of Things (IoT) platforms or data analytics. This could become a system-of-systems approach or smart city as a service.
- Apply a technology inventory that will support the set of objectives, as well as the information and data exchange governance requirements for the city and the public-private initiatives.

Sample Vendors

Accenture; Arup; Fluentgrid; Fujitsu; IBM; Microsoft; NEC; NTT DATA; Quantela; ZainTech

Gartner Recommended Reading

Predicts 2023: Sustainable Smart City Decision Making Using Urban Data

Case Study: An Intelligent Urban Ecosystem Approach to a Sustainable Smart City

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

Climbing the Slope

Shared Mobility

Analysis By: Shivani Palepu, Mike Ramsey

Benefit Rating: Moderate

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Shared mobility refers to transportation services or on-demand transit that are shared among users, either simultaneously, as a group or over time as personal rental. It encompasses the use of car sharing, ride-hailing, bike sharing or others that manage the pickup and drop-off, primarily through a mobile application. Shared mobility reduces the dependency on private vehicles and aims to optimize the use of shared resources, reduce congestion, and promote sustainability.

Why This Is Important

Shared mobility has fundamentally transformed the way people travel and transportation assets are utilized, creating a new channel and methodology for mobility. It allows for a more sustainable and accessible way to move around. It can also enhance the reach of public transportation, particularly in regions with limited transportation options. Shared mobility also addresses the challenge of first-and last-mile mobility which is a major bottleneck for transportation agencies.

Business Impact

Shared mobility, primarily through ride-hailing services, has had a huge impact on transportation by reducing private vehicles dependency. As shared mobility continues to grow, there may be an increased demand for technologies that enable efficient booking, payment processing and more. Shared mobility has also fueled the adoption of MaaS, which offers a common platform for booking, routing and payment for low-cost alternatives.

Drivers

- The return of workers to offices and urban areas, postpandemic rise in business and increased social travel had a positive impact on the use of shared mobility.

- Advancements in technology such as mobile apps, GPS trackers, real-time information, payment processing and more, have made it easier to access shared mobility services.
- The adoption of shared mobility would increase given the rise in electric vehicles adoption. In addition, the cost of operating ride-hailing vehicles should fall as more vehicles use electricity rather than fuel. This could also reduce pollution concerns in urban centers where the increase in traffic from ride-hailing initially raised concerns.
- The increase in usage of shared mobility modes to access mass transit systems as they integrate well with long-distance transportation modes.
- The proliferation of mobility-as-a-service platforms that connect different forms of transportation could increase demand for shared mobility services by making them easier to access.
- The rise of autonomous vehicles (AVs) could also increase adoption of shared mobility by making the system more swift and futuristic.

Obstacles

- The economics of shared mobility have always been a problem. Many shared mobility platforms have been unprofitable, although they are inching toward better results.
- User behavior and safety can be a major challenge in the adoption of shared mobility. Addressing issues like wearing helmets, thefts, vandalism or misuse of vehicles can pose a major challenge to operators.
- Changes in culture around working from an office versus at home and the corresponding vitality of urban centers could impede shared mobility. It may also shift the focus to active transportation like walking and bicycling.
- Laws in certain regions that require ride-hailing providers to be considered employees or limit them against taxi operators may change the structure of the primary companies offering services and make expansion difficult.
- Rapidly evolving market dynamics with changes in customer preferences, competitive pressure, regulations and technological advancements can pose a challenge for the operators.

User Recommendations

Transit agencies or service providers should:

- Form partnerships and integrate shared mobility services with public transport to provide effective door-to-door connectivity.
- Invest in data and technology to better understand the demand for shared mobility.
- Use shared mobility to provide transportation options for people who feel uncomfortable in public transportation or who aren't always able to use public transport, like the elderly.
- Enable payment or scheduling options that complement other public and private transportation options.
- Develop a MaaS platform to further support the integration of shared mobility with transportation systems. This will improve traffic congestion, to address pollution concerns and to even provide lower-cost transit.
- Prioritize sustainability by investing in electric vehicles and promoting bike-sharing.
- Be wary of investing in, or connecting with, services that skirt city regulations, because the services could quickly be frozen out for an individual town.

Gartner Recommended Reading

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

Quick Answer: How Can CIOs Establish a Successful MaaS Platform?

Microgrids

Analysis By: Ethan Cohen

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Definition:

A microgrid is a self-sufficient group of interconnected electrical loads and distributed energy resources that can operate as a stand-alone power system or be connected to the grid to provide optimization optionality. Microgrids commonly range in size from 100 kilowatts (kW) to 10s of megawatts (MW) and can connect to and disconnect from the grid. Microgrids can operate in both grid-connected and island modes based on technical and economic criteria to optimize energy cost and availability.

Why This Is Important

Microgrid uses include rural electrification, residential or community power networks, commercial, industrial, municipal, hospital and military base power grids. Microgrids leverage traditional and renewable generation sources. Microgrids offer a compelling alternative to traditional energy generation and distribution, using Internet of Things (IoT) to enable integrated control of distributed power generation assets.

Business Impact

Microgrids impact utility generation, distribution and energy retailing domains. They are becoming more important as utilities create new energy ecosystems and expand energy services offerings. Microgrids are also examples of energy technology consumerization, challenging the traditional business model of utility-provisioned energy delivered as a cloud service. By facilitating consumer integration into the energy market, microgrids are contributing to consumer energy management and the energy delivery infrastructure's geodesic transformation.

Drivers

Microgrids offer advantages to utilities and customers by improving energy efficiency, reducing transmission and distribution losses, improving reliability, reducing environmental impact and providing a more cost-efficient electricity infrastructure compared to the traditional electricity distribution grid, as they also:

- Provide local options regarding the choice of electricity generation source and supply, such as distributed renewable energy sources (particularly those that are for energy storage).
- Enable energy customers to self-provision for operational resilience and collaborate or partner with utilities to achieve specific outcomes.

- Support renewable energy and energy efficiency through a viable approach to local grid modernization while incorporating local distributed energy supplies and storage technologies to meet the specific needs of their constituents while networking with the main grid.
- Deliver benefits to utilities by supporting the central grid in handling sensitive loads and the variability of renewables locally and supplying ancillary services to the bulk power system.

Obstacles

- Microgrids do not have the same economies of scale and the coincident load factor of the centralized grid.
- The commercial integration of microgrids into energy markets will require a platform for the energy-sharing, resource-sharing and market-sharing economy.
- Technical constraints inhibit the integration of microgrids into distribution grids, including specific elements like dual-mode switching functionality, reliability, power quality and protection.
- Central electricity network operation impacts for microgrids require new utility systems, such as distributed energy resource management systems and advanced distribution management systems, which can be costly and complex to deploy.
- Microgrids must have mechanisms to regulate voltage and frequency in response to changes in load and system disturbances. This is because all power in microgrids comes from distributed generation resources and controllable loads within the microgrid, which typically requires investment in operational technology (OT) to perform distributed control.

User Recommendations

As microgrids progress into mainstream utility, CIOs should:

- Observe market developments in microgrid use cases, and evaluate what kinds of offerings might be advanced to develop new revenue, enhance resilience and improve energy provisioning.

- Enable the utility to quickly and thoroughly evaluate microgrid development and/or operation by developing minimum viable products for microgrid cases. Despite the significant promise and industry excitement about the concept, relatively few fully commercialized state-of-the-art microgrids have been deployed by utilities in many regions.
- Advance computational capabilities by improving physical models that leverage machine learning and automation.
- Dedicate some investment to a microgrid design authority to improve microgrid operations reliability, security and self-healing capabilities in intelligent grid operation for electricity distribution.

Sample Vendors

Alencon Systems; Ameresco; Generac Power Systems; NRG Energy; PowerSecure; Schneider Electric; Siemens; Veritone; Yokogawa Electric Corporation (PXiSE Energy Solutions)

Gartner Recommended Reading

2023 Utility Trend: Orchestrate Flexible Resources to Maintain Power System Operational Integrity

Last-Mile Delivery Solutions

Analysis By: Oscar Sanchez Duran, Carly West

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Last-mile delivery (LMD) solutions are specialized, customer-centric transportation management solutions that provide capabilities for routing deliveries to consumer homes. With some solutions extending the delivery service capabilities offered support options like store, curbside and locker box collections as well as return options. These solutions are the next generation of delivery solutions, adding additional capabilities, such as customer experience management.

Why This Is Important

Last-mile delivery solutions have grown due to the huge increase in digital commerce deliveries (including B2B e-commerce, direct-to-consumer, drop-ship, and digital marketplaces). Whereas VRS focused primarily on over-the-road fleets and movements for first mile, middle mile and last mile to businesses. These new LMD solutions mainly focus on deliveries to end consumers using either a company's own fleet, or outsourcing transportation with courier carriers and third-party logistics (3PLs).

Business Impact

LMD solutions provide benefits to e-commerce companies and other shippers focused on the last mile. They add incremental benefits to mature users of routing and scheduling, reducing costs and improving customer service in dynamic environments, and provide other options like sourcing transportation from third-party fleets. Additionally, LMD solutions can improve sustainability service levels, providing capabilities to allow end customers to choose more sustainable transportation options.

Drivers

- LMD solutions can dynamically recalculate and communicate a new route to drivers in real time. These solutions can automatically and proactively adapt to unforeseen events like traffic congestion notifications that will delay drivers and may warrant rerouting.
- As customer choice increases, LMD solutions provide ways to maximize fleet capacity, provide options to outsource transportation and consider multiple shipping from-to scenarios. Connection to courier carriers, and local and hyperlocal delivery carriers, including riders or crowdsourced delivery services are becoming increasingly important. The same applies to the delivery services supporting ship-from-store, curbside delivery and access to pick-up and drop-off networks.
- LMD solutions enhance the delivery experience by improving communication with the customer, considering changes throughout the day as variables of change continue to increase and click-to-door times continue to decrease.
- Meeting on-time appointment windows for delivery to home or office is important and a challenge. Consumers are seeking flexibility in delivery slots and are increasingly prone to changing the date and time of delivery according to their changing needs. Missed appointments require more dynamic updating of both routes and notification to customers of changed appointments.
- Sustainability capabilities are starting to be an intrinsic part of LMD solutions. Vendors are adding not only reporting and analytics on carbon emission, but also providing options to the users to add new services based on sustainable choices like moving the freight with electric vehicles.
- There is a higher demand for customer experience management during the pre- and postpurchase processes that connect to the cargo delivery. Providing a branded experience and capabilities to increase the range of customer choice while overpromising and impacting delivery operations are features considered in these applications.

Obstacles

- Not all users will need LMD solutions. Traditional VRS solutions will suffice for those users who are more first- and middle-mile-focused or who do not require to cover B2C use cases with focus on customer experience.
- Some companies operating with courier carriers and having very large volumes of parcel shipping might use multicarrier parcel management solutions instead.
- Many of these solutions have not yet developed capabilities for all segments of transportation (first, middle and last mile). So, we see end users struggling to figure out their entire transportation network with a common organization, process and technology. Many end users will continue to use multiple solutions, like transportation management systems, along with more traditional vehicle routing and last-mile solutions.

User Recommendations

- Determine if your organization might be a good candidate for LMD solution by mapping internal processes for high levels of change over the course of a delivery, or large focus and volume on last-mile delivery to consumers.
- Implement the drivers to define specific use cases above before investigating solutions to ensure the right fit for your operations.
- Understand the limitations of last-mile applications. While they can provide customer experience management and delivery orchestration capabilities, they might feel short in some use cases.
- Companies need to balance the trade offs between optimal and feasible routes as businesses have become more dynamic and customers more demanding.

Sample Vendors

Bringg; DispatchTrack; FarEye; Locus; LogiNext; OneRail; Onfleet; Tiramizoo; Urbantz; WOOP

Gartner Recommended Reading

Market Guide for Last-Mile Delivery Technology Solutions

How Retail's Last Mile Must Evolve to Become a Two-Way Street

Beyond the Amazon Effect: Why B2B Needs to Evolve Its Last-Mile Strategy

Distributed Generation

Analysis By: Lloyd Jones

Benefit Rating: Transformational

Market Penetration: More than 50% of target audience

Maturity: Mature mainstream

Definition:

Distributed generation (DG) is an energy supply method that situates generation at or near where it's used. DG may include a mini-hydro, diesel, biofuel, wind, solar or fuel cell, and may be customer-owned. DG is a subset of distributed energy resources (DERs) and includes on-site storage. Wider adoption transforms centrally managed, radial delivery networks to more complex networks requiring advanced hybrid engineering control and economic-incentive-based distribution network operating modes.

Why This Is Important

Utilities may deploy DG as part of a strategy to manage the timing of network upgrades. DG may be used temporarily or permanently to alleviate congestion and assure energy availability. Energy-intensive customers in industrial sectors seeking to secure energy availability have invested in DG. Commercial and groups of residential customers are investing in DG. DG adoption challenges legacy utility business models, raising questions about how the grid will be operated and monetized.

Business Impact

DG deployment has transformational impacts on utilities. DG gives energy customers more choices, and may increase the installed base of environmentally and economically sustainable generation — reducing greenhouse gasses — and may encourage improved energy efficiency. However, DG creates significant challenges to grid operations, even while improving energy resilience. DER in general, and DG in particular, are the main drivers of the energy transition.

Drivers

- According to the Bloomberg New Energy Outlook 2021 report, the cost of solar declined by 85% from 2010 to 2021 — close to low-triple-digit price performance improvement in less than a decade. However, costs are expected to rise in 2022 for the first time in 10 years due to supply chain and commodity price rises.
- The price performance improvement is the main driver behind rapid DG (renewable) adoption by consumers. Exponential technology advances at the grid edge are making it simpler, easier and less expensive for businesses and consumers to begin self-generation. They are also making it easier for consumers to actively manage their interaction with energy markets by controlling when to buy, store or sell energy back to the grid.
- Regulatory mandates, such as FERC 2222 of 2021, mandate equal treatment of smaller-scale DG on the wholesale markets.
- Jurisdictions that actively pursue renewable energy by supporting feed-in tariffs and net metering arrangements are more conducive to DG deployment. For example, California expects that one-fourth of new-generation resources will come on the customer's side of the meter (mostly rooftop solar). The International Energy Agency World Energy Outlook forecasts that incremental solar photovoltaic deployments will account for more than 70 GW of the combined future capacity additions through 2040 — the largest share of total additional capacity by type.
- Engine innovation is accelerating, with smaller, quieter units coming to market, including modular and linear engines that are multifueled.

Obstacles

- Integrating DG into electric distribution networks is a significant challenge requiring electric delivery operations knowledge, and expertise in software and hardware design.
- Integrating DG into utility business operations requires utilities to serve a more-dynamic, decentralized grid and respond to diverse prosumer and business partner ecosystems.
- Most utilities have had little incentive from regulators to pursue DG. Few utilities have an organizational structure ready to coordinate and facilitate a vast array of third parties with interests in DG expansion.
- DG interconnection standards are maturing in particular, following the release of the IEEE 2030.5 standard; however, regulatory oversight is still a patchwork of interconnection rules. Issues with sitting and permit costs still limit adoption.
- National grid codes need to be updated to support interconnection applications.

User Recommendations

- Watch out for transmission and distribution asset deferral benefits, but have backup plans if the DG technology has an unplanned outage.
- Propose incentives to regulators that would help them support cost-effective nonwire alternatives to traditional utility wire infrastructure upgrades while adhering to their service mandate.
- Review the information management and communication effects of DG growth, such as the need to expand communications networks and historian systems. Because a significant percentage of DG will be deployed by customers in the form of renewable generation, it will also enable consumer participation in carbon dioxide abatement.
- Treat DG as a part of overall DER strategy. That will require investment in distributed energy resources management systems or modification of advanced distribution management systems to address the needs of DG orchestration.

Sample Vendors

Ballard Power Systems; Bloom Energy; Capstone Green Energy; Caterpillar Energy Solutions; ITM Power; Plug Power; Rolls-Royce; Tesla; Wärtsilä

Gartner Recommended Reading

The Energy Transition Question: Do We Need the Grid?

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

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Market Guide for Distributed Energy Resource Management Systems

Building Information Modeling

Analysis By: Marc Halpern, Bettina Tratz-Ryan

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Building information modeling (BIM) is the discipline supported by software to capture, organize and manage information needed to design, create, monitor, repair, evolve and operate facilities from earliest conception to demolition.

Why This Is Important

Increases in regulations governing design, construction, operations and maintenance of facilities compounded by the number of roles involved in these activities require better means of managing and accessing information. So, organizations in many industry sectors including construction, government, manufacturing and retail need better means of organizing and accessing content about their facilities to streamline facilities design, construction, management, operations, modernization and demolition.

Business Impact

BIM delivers the following benefits:

- Reduces lost time and unnecessary costs associated with using wrong or out-of-date content throughout the life cycles of facilities.
- Improves ability to find and access content to support any activity such as facilities design, construction, operation, upgrade, maintenance and demolition of facilities.

- Improves collaboration across many roles responsible for the life cycles of facilities.
- Enhances sustainability and circularity over the life cycles of facilities.

Drivers

- As the costs of constructing and operating facilities continue to rise, facility owners, construction firms and operators seek means to increase efficiency of life cycle activities by reducing cost and time.
- Product development team members working from remote locations, instead of at a central location, need a platform with rich collaboration capabilities that also includes requisite design and engineering functionality.
- Technology advances and growing experience with BIM encourages more companies to adopt it.
- Prevalence of SaaS for other business software encourages cloud-native BIM.
- Manufacturers, utilities and architectural engineering and construction firms seek better means of complying to a growing number of regulations (such as those here in Six construction regulatory issues looming in 2020 by Construction Management) that they believe BIM will support more efficiently.
- Stakeholders in facilities seek to reduce costly mistakes with BIM by enabling better access to more timely and accurate information.
- BIM enables improved collaboration across roles participating in life cycle activities from remote locations.

Obstacles

- Engineers and contractors are deeply invested in their current culture and processes, making it difficult to adapt to new ways of working that BIM requires.
- Reaching consensus on BIM priorities and architecture proves challenging given the number of involved roles both inside and outside an enterprise.
- There will be a need for a champion investor.
- The lack of digitized data, especially among constructors, poses challenges to BIM adoption.
- BIM champions struggle to make compelling business cases for the investment.
- Building BIM content in proprietary design software formats will decrease its utility over time, cause vendor lock-in and increase the cost to maintain BIM.
- BIM projects will fail if scope creep creates higher-than-expected costs and lower-than-expected ROI. Insufficient supplier, partner and customer participation in BIM initiatives can lead to gaps in key content.
- Inflexible or incorrect BIM model design undermines future usefulness or possibly makes it obsolete before the end of a facility's service life.

User Recommendations

- Reduce the risk of failed BIM implementations by phasing the implementations into smaller, focused projects that build upon each other.
- Structure BIM initiative using governance or maturity models. Use both the BSI Levels 0 through Level 4, and incorporate 2D BIM to 7D BIM (as explained by NBS in BIM Levels explained) categories of data as the company moves from one level of BIM maturity to the next.
- Address BIM data architecture challenges by assigning IT architects to work with key BIM stakeholders.
- Encourage BIM adoption by redefining job performance metrics that encourage potential users to adopt BIM.
- Assign a BIM lead to run a project defining corporate standards for creating and modifying BIM models, and establish a training program to educate the user community.

Sample Vendors

Asite; Autodesk; Bentley Systems; Hexagon; Nemetschek Group; RIB Software; Trimble

Gartner Recommended Reading

Innovation Insight for Building Information Modeling

Creating Sustainable and Innovative Smart Buildings Through Data

Appendixes

See the previous Hype Cycle: Hype Cycle for Smart City Technologies and Solutions, 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)

Evidence

[1] Global Covenant of Mayors for Climate & Energy (Homepage), Global Covenant of Mayors for Climate & Energy.

Document Revision History

Hype Cycle for Smart City Technologies and Solutions, 2022 - 22 July 2022

Hype Cycle for Smart City Technologies and Solutions, 2021 - 21 July 2021

Hype Cycle for Smart City Technologies and Solutions, 2020 - 4 August 2020

Hype Cycle for Smart City Technologies and Solutions, 2019 - 2 August 2019

Hype Cycle for Smart City Technologies and Solutions, 2018 - 1 August 2018

Hype Cycle for Smart City Technologies and Solutions, 2017 - 2 August 2017

Hype Cycle for Smart City Technologies and Solutions, 2016 - 15 July 2016

Hype Cycle for Smart City Technologies and Solutions, 2015 - 27 July 2015

Hype Cycle for Smart City Technologies and Solutions, 2014 - 22 July 2014

Hype Cycle for Smart City Technologies and Solutions, 2013 - 29 July 2013

Hype Cycle for Smart City Technologies and Solutions, 2012 - 30 July 2012

Hype Cycle for Smart City Technologies and Solutions, 2011 - 28 July 2011

Recommended by the Author

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Understanding Gartner's Hype Cycles

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

Tool: AI Use Cases for Smart Cities and Intelligent Urban Ecosystems

From Smart City to Intelligent Urban Ecosystem — Unlocking Data Value Is the Key to Cities' Industrial Partnerships

Table 1: Priority Matrix for Smart City Technologies and Solutions, 2023

Benefit ↓	*Years to Mainstream Adoption*			
↓	***Less Than 2 Years*** ↓	***2 - 5 Years*** ↓	***5 - 10 Years*** ↓	***More Than 10 Years*** ↓
Transformational	Distributed Generation	City Operations Center Data Exchange Edge Computing Smart City Framework	Circular Supply Chain Greenfield Smart City Framework Smart and Sustainable Building Urban Sustainability and COP 26	Artificial General Intelligence
High	Digital Ethics Edge AI Last-Mile Delivery Solutions	5G Building Information Modeling Civic and Community Development Digital Twin of a Citizen Digital Twins of Government Intelligent Street Pole Smart City as a Service Smart City Regional Governance Supply Chain Cybersecurity Water Management Analytics	Energy-Water Nexus Intelligent Connected Infrastructure Microgrids Smart City Transportation Strategy	

Benefit ↓	*Years to Mainstream Adoption*			
↓	***Less Than 2 Years*** ↓	***2 - 5 Years*** ↓	***5 - 10 Years*** ↓	***More Than 10 Years*** ↓
Moderate	Shared Mobility			
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)