pwc

Empowering the future of cities through a cognitive city operating system

November 2025

Foreword

Hazem Galal

Global Cities & Local Government Leader and Global Smart Mobility Co-Leader, PwC Middle East

Rajat Chowdhary

Partner, Technology Consulting, PwC Middle East

Varun Paul

Partner, Technology Consulting, PwC Middle East

"Cities are redefining the boundaries of human progress. As the pace of urbanisation accelerates, city leaders are being challenged to manage complexity on a scale never seen before. The challenge is not only to improve efficiency but to achieve coherence across policy, infrastructure, experience and technology.

The concept of a cognitive city operating system marks a pivotal shift from managing infrastructure to orchestrating intelligence across the entire urban fabric. This transition toward cognitive and adaptive cities will be central to achieving long-term sustainability, competitiveness and citizen well-being worldwide."

"The cognitive city operating system offers a new way to think about how cities can harness technology to become intelligent, resilient and inclusive. This paper captures the shift from fragmented smart initiatives to a unified ecosystem that enables anticipation, collaboration and continuous improvement.

As the physical and digital worlds converge, this kind of connected urban intelligence will be essential for cities seeking to remain responsive, inclusive and ready for the future."

"Technology has become the foundation of modern cities, influencing decisions that affect millions of lives every day. Yet progress depends not only in deploying tools but on building systems that can learn, adapt and anticipate change.

The cognitive city operating system brings this to life by integrating artificial intelligence, digital twins and interoperable platforms within a single secure framework. It represents the next stage of city management where insight drives foresight, operations are predictive and leadership is rooted in transparency and trust."

Contents

1. Executive summary

Cities are at a decisive moment in their evolution. As cities grow and digital systems become embedded in daily life, progress is shifting from how efficiently cities operate to how intelligently they can think and adapt. The challenge for city leaders is to create connected systems that anticipate change and respond in real time.

The cognitive city operating system enables this transformation. It is a unifying layer that links data, technology and governance across the urban landscape, enabling cities to move beyond fragmented initiatives toward integrated and adaptive intelligence. Through this approach, mobility data can inform healthcare planning, climate sensors can guide infrastructure design and digital twins can model future growth to shape better decisions.

This orchestration rests on five core building blocks:

- Human-centric design and engagement: Places citizens at the core of city systems ensuring technology remains inclusive, participatory and adaptive to evolving urban needs

- Integrated sensing and data awareness: Combines physical and digital sensing to create a continuous feedback network that drives real-time situational awareness and predictive management

- Cognitive intelligence and analytics engine: Leverages AI, analytics and data fusion to transform diverse city data into actionable intelligence for proactive decision-making.

- Service enablement and orchestration: Integrates government, private and community systems through intelligent orchestration, enabling seamless collaboration and data-driven coordination

- Data intelligence unification: Orchestrates domain-specific insights to enable cross-domain fusion, interoperability and ethical data governance

- Unified reporting and dashboarding: Delivers real-time visibility and predictive insights through advanced analytics and interactive dashboards, empowering informed, data-driven decision-making across city operations

- Governance, security and interoperability: Built on robust governance and multi-layered security, ensuring trust, accountability and resilience across the entire urban ecosystem

Realising this vision requires collaboration among governments, businesses, academia and citizens to ensure that cognitive systems strengthen trust and advance collective well-being in the cities of the future.

2. The evolving urban equation: Cities at an inflection point

## The evolving urban equation: Cities at an inflection point

Cities have long been the engines of human progress, cultural exchange and social transformation. More than half of the world's population now lives in cities, a figure expected to reach almost 70% by 2050 [1].This is likely to intensify challenges such as congestion, climate stress, inequality, resource constraints and rising expectations for seamless services. Traditional models of city management often fragmented across sectors and agencies are no longer adequate to meet the scale and complexity of these demands.

In response to the pressures of rapid urbanisation, many cities are deploying sector-specific intelligent solutions to drive efficiencies, improve the quality of living and support sustainability. Singapore has piloted autonomous shuttles to enhance connectivity, Barcelona has pioneered intelligent waste systems to reduce costs and environmental impact[2]. and London has deployed sensors enables by Internet-of-Things (IoT) to improve air quality monitoring[3]. These initiatives illustrate how leading cities are harnessing technology to address urban pressures through targeted interventions.

Investing heavily in "smart" initiatives ranging from intelligent transport systems and digital healthcare to renewable energy grids and e-government services. Yet much of this progress remains sector-specific and siloed, delivering incremental efficiency gains without unlocking the wider potential of interconnected urban ecosystems. The next phase of urban evolution demands a shift from isolated smart projects to an integrated, adaptive and citizen-first model of governance.

The concept of a cognitive city operating system defines this shift. It acts as the orchestration layer that unifies data, intelligence and services across the urban fabric. Much like a digital backbone, it enables cities to function as cohesive ecosystems rather than collections of disconnected projects. By embedding artificial intelligence, advanced analytics and ethical governance at its core, it empowers cities to anticipate challenges, respond dynamically and continuously.

The following sections examine the limitations of current urban models, outline the building blocks of the cognitive city operating system and highlight the strategic choices and enablers needed for successful implementation. It also offers a forward-looking perspective to help city leaders, technology partners and civic stakeholders understand not only what digital transformation entails, but how to build cities that think, respond and care.
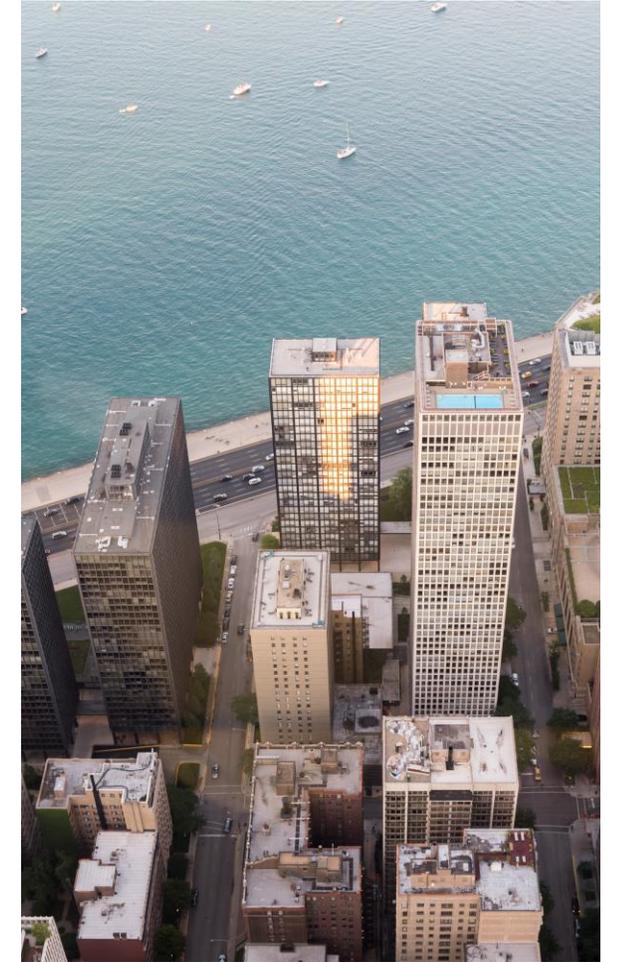
3. Enabling unified and integrated urban intelligence

a. From fragmentation to orchestration

The siloed nature of smart city initiatives, often invisible at first, has become one of the most significant barriers to cities realising their full potential as cognitive ecosystems. Although sector-specific solutions can deliver efficiencies, they often operate in isolation with limited data sharing, creating parallel systems that optimise within their own boundaries but fail to contribute to the city's broader urban intelligence.

This fragmentation is often seen as a technological issue, yet it also exposes a deeper challenge of governance. City agencies remain constrained by departmental mandates and budget silos, while proprietary vendors technologies reinforce separation and limit collaboration. As a result, smart city initiatives are often seen as disconnected projects rather than elements of a unified cognitive ecosystem. Many cities therefore risk being defined by disconnection rather than cohesion.

This fragmented model may capture incremental gains, but it undermines the network effects that amplify value across sectors and prevents cities from realising transformative outcomes. To move beyond these limitations, cities must orchestrate their systems through a unifying cognitive layer that harmonises data, aligns stakeholders and enables them to operate as intelligent and adaptive ecosystems.

The cognitive city operating system enables this orchestration through a unified intelligence layer that enables seamless data exchange, harmonises sectoral platforms and supports real-time decision-making across agencies and domains. It allows cities to harness network effects across sectors. Public transport data can link with tourism platforms to improve visitor journeys, environmental monitoring can inform public health for proactive care and traffic data can be synchronised with emergency services to reduce response times.

This orchestration is not only about technology but about governance, standards and trust. It requires open architectures that prevent vendor lock-in, shared data frameworks guided by ethics and transparency and cross-sector analytical models that encourage collaboration rather than competition. With these foundations, the cognitive city operating system enables cities to evolve into adaptive and anticipatory systems that continuously learn, respond and improve.

Moving from fragmentation to orchestration is the critical leap that enables cities to unlock the full potential of cognitive urban ecosystems, ensuring they are not just technologically advanced but also adaptive, resilient and citizen-centric.
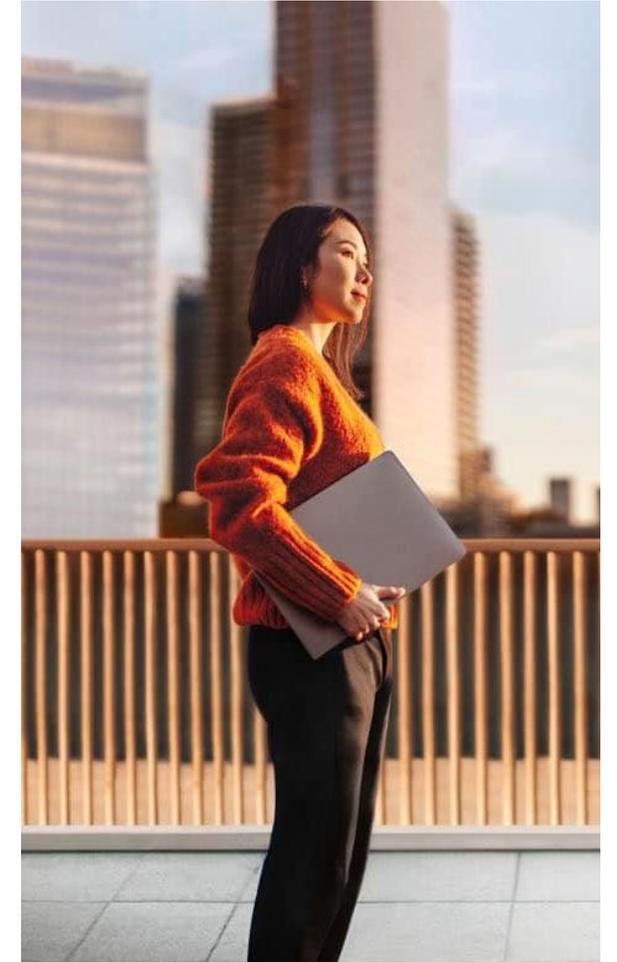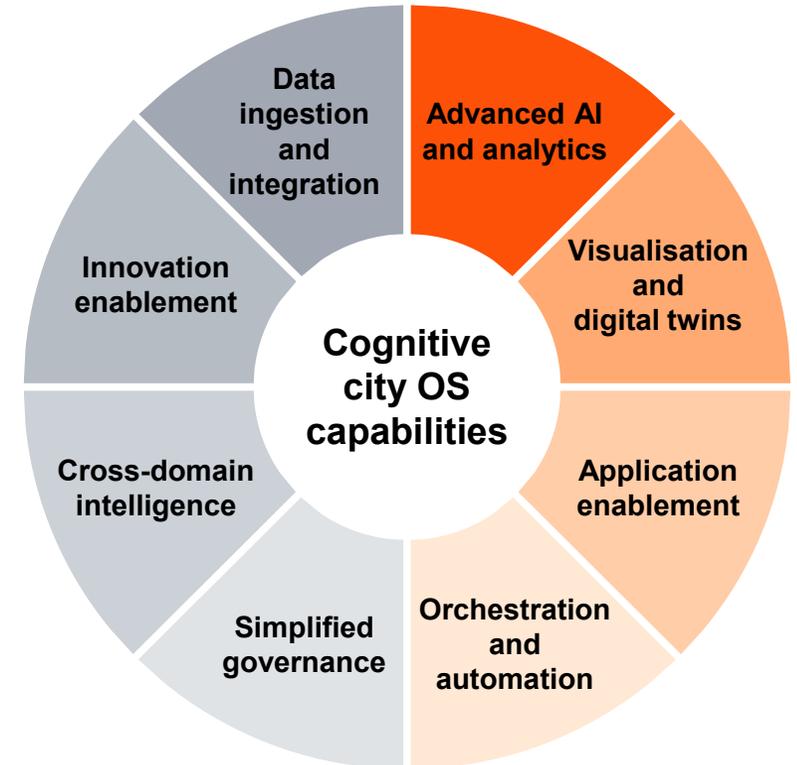
3. Enabling unified and integrated urban intelligence

a. From fragmentation to orchestration

A cognitive city operating system delivers a wide range of capabilities that underpin cognitive city operations:

▶ Enables machine learning, predictive modelling, and generative AI to support planning, anomaly detection, and citizen personalisation

▶ Creates real-time and simulated representations of city infrastructure, enabling scenario planning and operational monitoring

▶ Provides APIs, SDKs, and low-code environments for building and scaling urban applications

▶ Automates workflows across departments and services, reducing manual interventions and improving responsiveness

▶ Offers policy enforcement, access control, and compliance management across digital assets.

▶ Fuses sectoral and integrated operations centre specific knowledge into unified city intelligence, enabling holistic decision-making

▶ Serves as a launchpad for citizen-centric services, urban startups, and public-private innovation.

▶ Seamlessly collects and harmonises data from sensors, systems, and citizen inputs across domains

3. Enabling unified and integrated urban intelligence

b. Enabling cross-sector use cases

The real strength of a cognitive city operating system lies not in optimising individual sectors but in its ability to weave intelligence across domains. By breaking down silos and enabling systems to share insights, cities can unlock entirely new forms of value that no sector could deliver on its own. Some of the leading examples that emerge when systems function as part of a connected, orchestrated ecosystem are as follows.

Non-Exhaustive

3. Enabling unified and integrated urban intelligence

From weather insights to intelligent road safety

Cities can harness street-level environmental intelligence by capturing real-time data on icy roads, heavy rainfall or reduced visibility to manage traffic operations proactively. By turning these insights into dynamic actions, authorities can optimise mobility flows, ease congestion and improve road safety for all users. This data-driven approach strengthens network resilience and lays the groundwork for smarter, more sustainable urban mobility.

In Copenhagen, a network of environmental sensors captures weather and pollution data across the city. Real-time insights stream into the traffic control centre, informing dynamic signal timing and operational adjustments. By fusing environmental monitoring with traffic management, the city has improved road safety and congestion management[4].

Non-Exhaustive

Weather insights <> intelligent road safety

Insights on real-time weather conditions leveraged for optimizing mobility flows, minimizing congestion, and strengthening road safety.
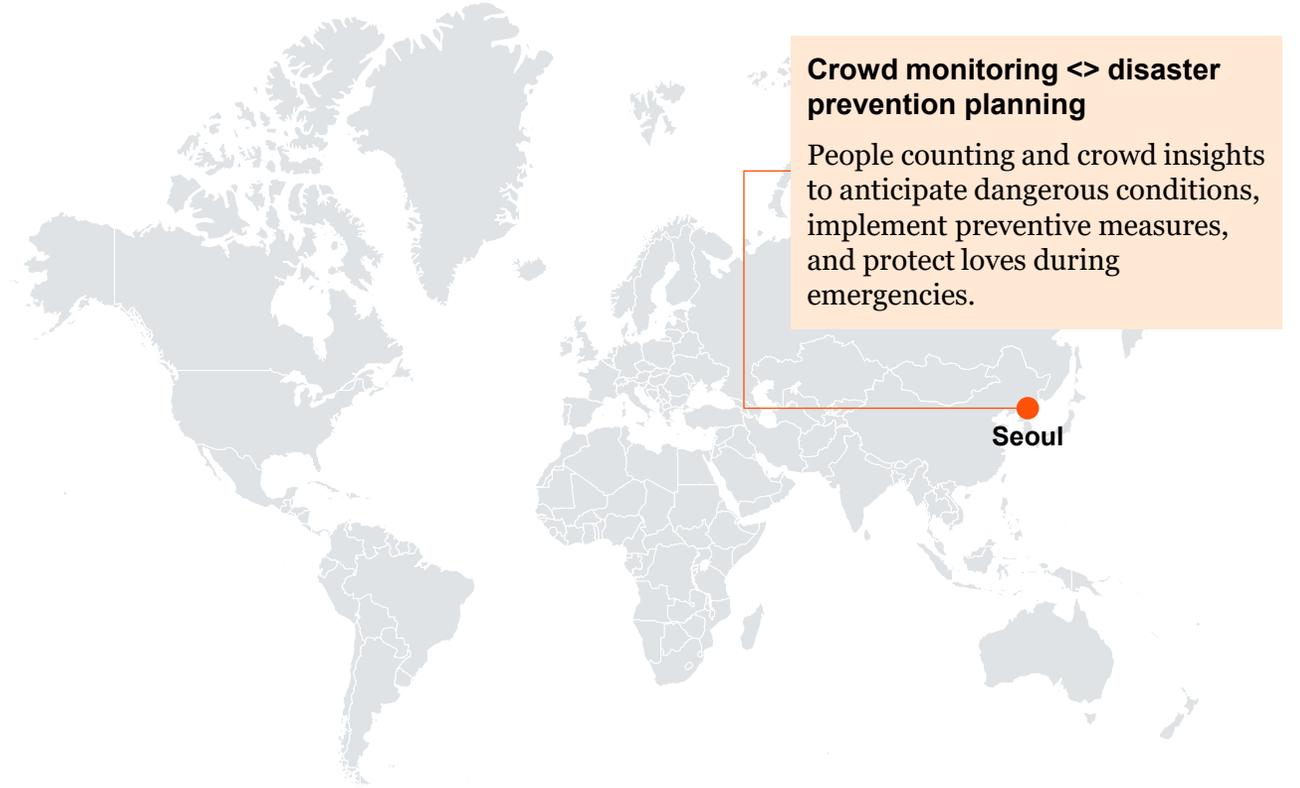
Copenhagen
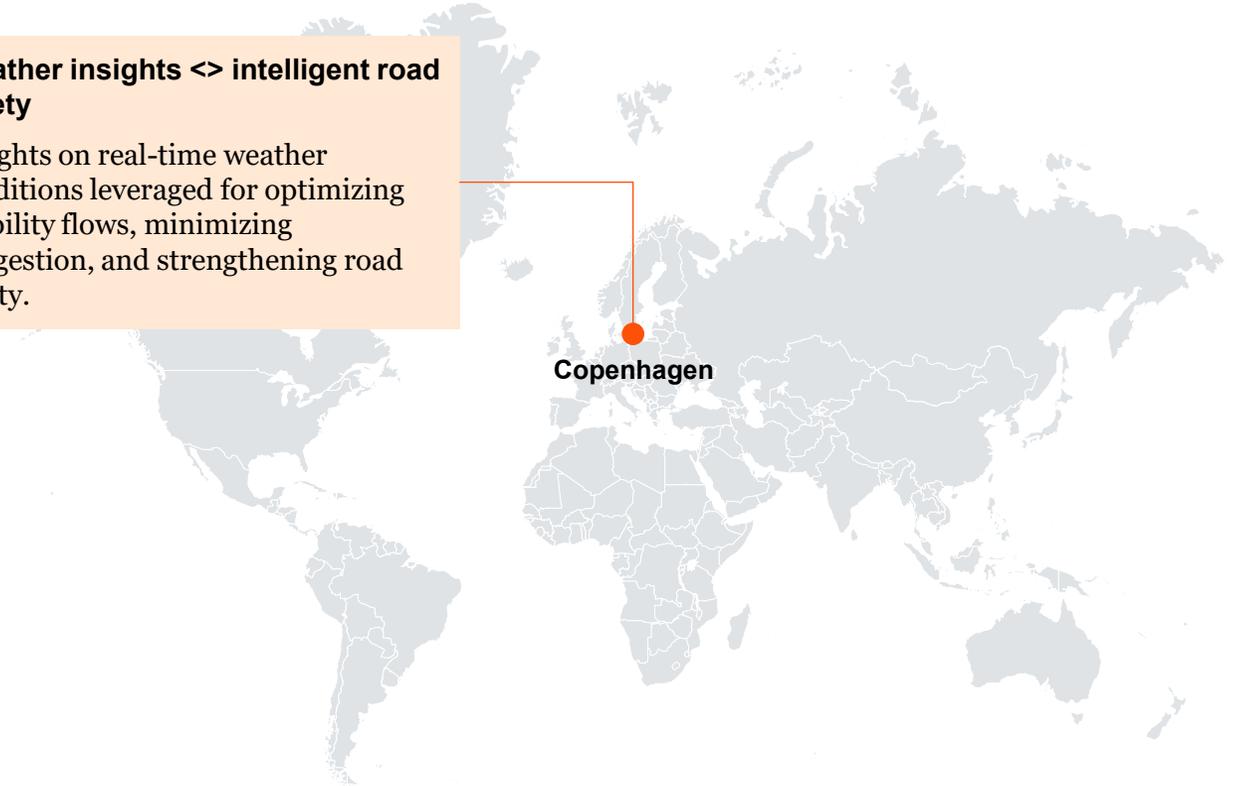
3. Enabling unified and integrated urban intelligence

From crowd monitoring to disaster prevention planning

Cities can significantly reduce disaster risks by embedding intelligent monitoring systems into their urban safety infrastructure. People-counting and crowd detection technologies provide early warning signals by automatically assessing density levels in real time. When integrated into disaster management frameworks, these insights enable authorities to anticipate hazards, take preventive measures and protect lives during emergencies.

Seoul has implemented an intelligent disaster-prevention system that uses AI-powered crowd monitoring to detect abnormal congestion levels before it escalates. The system sends automatic alerts to disaster-safety control centres, police and fire services, enabling coordinated action such as restricting vehicle entry, diverting pedestrian flows, or deploying emergency responders. By embedding these tools into operations, Seoul mitigates crowd-related hazards before they become crises[5].

Non-Exhaustive

Crowd monitoring <> disaster prevention planning

People counting and crowd insights to anticipate dangerous conditions, implement preventive measures, and protect loves during emergencies.

Seoul

3. Enabling unified and integrated urban intelligence

From traffic intelligence to future-ready urban development

Cities can transform planning by feeding traffic data into digital twin platforms to simulate the ripple effects of new developments. Combining mobility insights with environmental and infrastructure models allows planners to forecast congestion, pollution and service demand well before construction begins. This enables proactive changes to project design and zoning, ensuring developments strengthen connectivity rather than create bottlenecks.

Singapore's Virtual Singapore digital twin platform fuses detailed traffic datasets with dynamic 3D urban models to simulate development scenarios. Before major initiatives, such as the construction of new highways or event centres proceed, the platform enables authorities to assess potential impact on traffic flows, pollution and neighbourhood liveability. This forward-looking intelligence helps balance economic growth and sustainability, mitigate long-term congestion risks and ensure investments are efficient today [6].

Non-Exhaustive

Singapore

Traffic intelligence <> future-proof urban development

Digital twin platform that fuses detailed traffic datasets with dynamic 3D urban models to simulate complex development scenarios
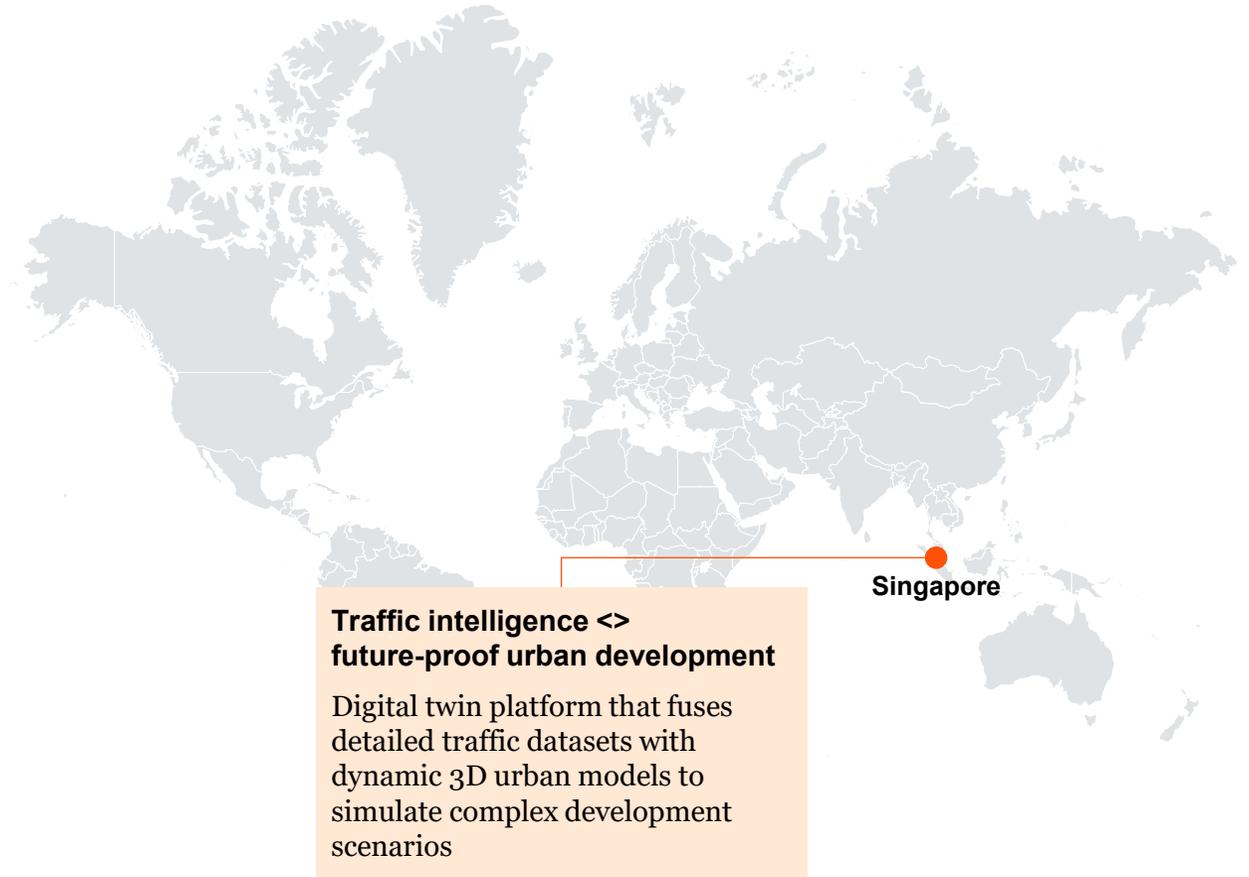
3. Enabling unified and integrated urban intelligence

From climate sensing to proactive emergency preparedness

Cities can strengthen long-term resilience by using climate intelligence to predict flood zones and broader climate risks. These insights enable planners and engineers to make data-driven adjustments to zoning regulations, drainage and building codes so infrastructure is designed for future impact. By embedding risk data into planning decisions, cities reduce vulnerabilities, safeguard communities and lower recovery costs after extreme events.

In Varanasi, India, authorities deployed a LiDAR-based urban digital twin to forecast flood risk. Insights have guided emergency preparedness and informed long-term city planning and infrastructure investment, showing how cross-sector intelligence delivers immediate protection[7].

Non-Exhaustive

Varanasi

Climate sensing <> proactive emergency preparedness

Climate intelligence insights to prediction of flood zones and climate risks to empower make data-driven adjustments to zoning regulations, drainage networks & buildings, codes

3. Enabling unified and integrated urban intelligence

From pedestrian flow analysis to smarter public transport planning

Cities can enhance sustainable mobility by integrating pedestrian-flow intelligence into design and transit planning. Analysing real-time crowd dynamics helps identify congestion hotspots, optimise pedestrian routes and improve accessibility at transfer hubs. These insights support higher service levels, encourage public transportation use, guide streetscape redesign and strengthen safety. Embedding pedestrian-centric insights improves safety, eases traffic pressure and supports a shift to greener transit.

In Milan, participation in the CityFlows project uses real-time crowd monitoring at key streets and transit hubs to reshape how pedestrian spaces interact with public transport. What began as a tool to manage congestion and protect walkers is evolving into a broader strategy for reshaping urban mobility[8].
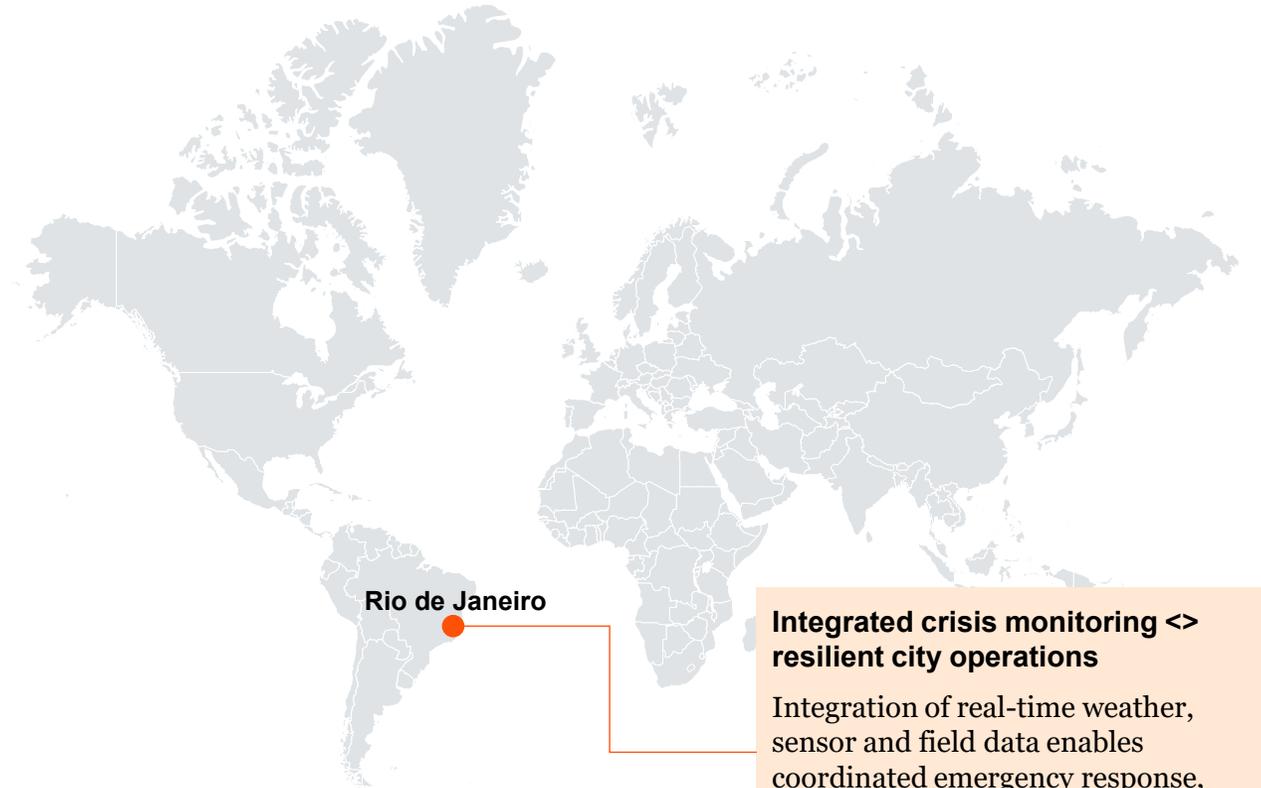
Non-Exhaustive

Milan

3. Enabling unified and integrated urban intelligence

From integrated crisis monitoring to resilient city operations

Cities can strengthen urban resilience by integrating weather, mobility and public safety data into unified operations. Real-time environmental insights combined with coordinated field responses help anticipate disruptions, reduce risks and maintain essential services. This data-driven integration transforms emergency management from reactive crisis handling into proactive, predictive city governance enhancing safety, transparency and public trust.

In Rio de Janeiro, the City Operations Centre (COR) brought together more than 30 municipal agencies to manage risk prevention, daily operations and major public events. It began as a response to frequent flooding but now functions as the city's central hub for data-driven coordination. By merging rainfall forecasts, sensor data and live field updates, COR enabled faster decision-making and real-time public communication. The initiative has evolved into a model for resilient urban management, demonstrating how cross-sector collaboration and integrated data can future-proof cities against climate and operational challenges[9].

Non-Exhaustive

Rio de Janeiro

Integrated crisis monitoring <> resilient city operations

Integration of real-time weather, sensor and field data enables coordinated emergency response, faster decision-making and improved public communication to enhance urban resilience and safety.

3. Enabling unified and integrated urban intelligence

The examples above reflect a global shift as cities test integrated models across multiple domains. A cognitive city operating system accelerates this transformation by providing the foundation to coordinate, align and scale efforts. By moving beyond isolated pilots and enabling initiatives to operate as a cohesive ecosystem, cities can adapt, learn and evolve continuously, delivering sustainable impact and future-ready outcomes.

Non-Exhaustive

4. Cognitive city operating systems: Unpacking the core building blocks

The cognitive city operating system serves as the unifying intelligence layer that transforms fragmented initiatives into a cohesive, adaptive.
To work effectively, it must be built on core building blocks intertwined with the city technology layers that together ensure citizen-centric outcomes. [10]

- **Human-centric design and engagement**

At its foundation, the cognitive city operating system emphasises human-centred unification aligning city systems around the needs, behaviours and feedback of citizens. By enabling participatory engagement and feedback loops, the cognitive city operating system ensures that all technological advancements supporting equitable service delivery remain contextual, inclusive and adaptive to evolving urban challenges.

- **Integrated Sensing and data awareness**

The cognitive city operating system enables comprehensive city-wide awareness by combining physical sensing through IoT sensors and edge devices with digital sensing from social, transactional and infrastructural data sources. It leverages these models to create a continuous feedback network allowing the city to listen, learn and respond dynamically. This enables real-time situational awareness and predictive management of urban services.

- **Cognitive intelligence and analytics engine**

The cognitive engine within the operating system functions as the intelligence core of the platform. Leveraging AI, advanced analytics and data fusion, it transforms heterogeneous city data into actionable, cross sectoral insights. It supports anomaly detection, behavioural analysis and decision support enabling cities to shift from reactive management
to predictive decision making.

4. Cognitive city operating systems: Unpacking the core building blocks

- **Service enablement and orchestration**

Through intelligent service orchestration and automation mechanisms, the cognitive city operating system integrates government, private and community systems into a unified digital ecosystem. This facilitates coordinated, data-driven action across city services and ensures interoperability, scalability, and seamless collaboration across domains.

- **Data intelligence unification**

The cognitive city operating system orchestrates domain specific insights from structured and unstructured data stored within secure and scalable repositories. It enables cross-domain data fusion, fostering interoperability across diverse systems while ensuring compliance with data privacy, ownership and ethical governance standards.

- **Unified reporting and dashboarding**

The cognitive city operating system powers a unified monitoring and reporting framework that delivers real-time visibility into city-wide operations and performance. Through advanced analytics and interactive dashboards, it identifies anomalies, predicts emerging challenges and provides actionable insights to support informed and data-driven decision-making.

- **Governance, security and interoperability**

The cognitive city operating system is governed by a robust framework of policy alignment, data ethics and cross-sector collaboration ensuring it operates as an open, transparent and scalable ecosystem. Supported by a multi-layered security and interoperability architecture, it incorporates advanced security mechanisms to safeguard citizen data and public systems while fostering trust, accountability and resilience across the urban ecosystem.
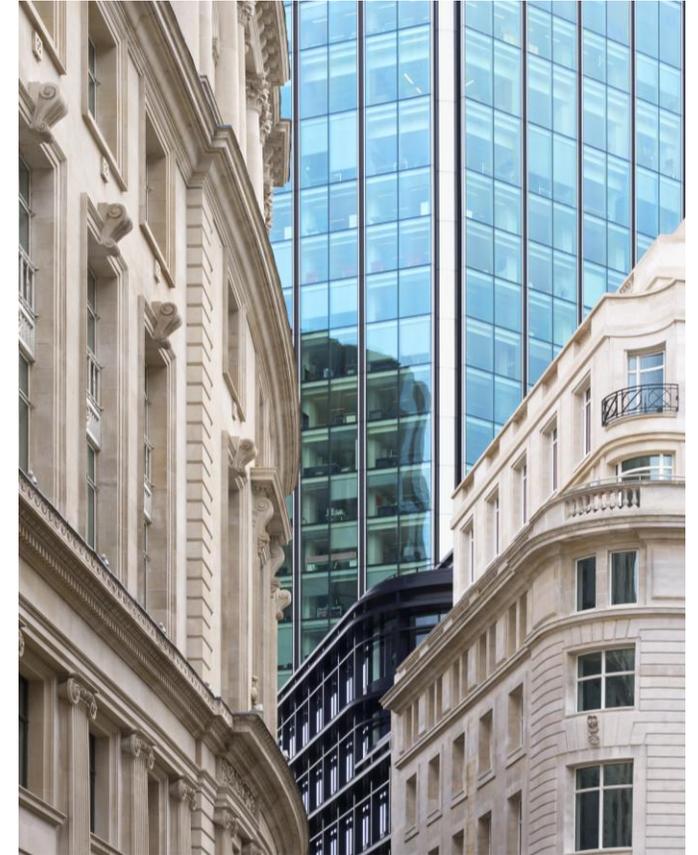
4. Cognitive city operating systems: Unpacking the core building blocks

a. Navigating platform architectures: Constructing strategic choices

As cities embark on their journey toward cognitive operating models, the choice of platform architecture becomes one of the most consequential strategic decisions. This choice is far more than a technical consideration as it fundamentally determines how data flows, how services interoperate and how governance is applied. Every city's context from institutional structures to policy priorities and digital maturity demands a tailored approach, making architecture design a strategic differentiator rather than a one-size-fits-all solution.

Drawing on global experience and extensive analysis of leading urban initiatives, three dominant platform archetypes have emerged, each reflecting distinct strategic approach to building the digital core of a cognitive city:

1 **City intelligence platform:** An AI-centric model designed as the city's "digital brain", enabling predictive analytics, cognitive automation and cross-domain intelligence to support anticipatory decision-making. This is ideal for cities seeking to move beyond reactive service delivery and embrace predictive, adaptive and proactive governance. It enables city leaders to simulate scenarios, anticipate disruptions and optimise resources with precision.

2 **City data and integration platform:** A data-driven model built around openness and interoperability, designed to unify data across departments and sectors, enable analytics-led policy and planning and democratise access to trusted data. This is beneficial for cities seeking to consolidate fragmented systems, establish strong data governance and foster innovation through open ecosystems. Emphasising accessibility, openness and modularity, it acts as a powerful enabler of co-creation and economic growth.

3 **Vertically integrated urban operating system:** A proprietary, end-to-end system that connect IoT devices, ingests and processes data and delivers insights and analytics for urban operations through a tightly coupled architecture. It suits cities seeking quick wins, sectoral transformation or public-private partnerships (PPPs) in high-priority areas. It focuses on operational efficiency, resource optimisation and turnkey implementation typically led by specialised vendors or consortia.

4. Cognitive city operating systems: Unpacking the core building blocks

Each archetype reflects a different philosophy of urban enablement, from holistic intelligence to modular integration to sectoral transformation. While these three archetypes represent the prevailing models shaping today's urban digital platforms, the rapidly evolving needs of cities call for these platforms to further mature and evolve into a unified, cohesive cognitive city operating system.

The following table compares the three existing archetypes, outlining their respective strategic focus, key features and strengths to support informed decision-making as cities embarking on their cognitive journey.

Key parameters	City intelligence platform	City data and integration platform	Vertically integrated urban operating systems
Strategic focus	• A centralised, AI-driven "city brain" focused on optimising city-wide operational efficiency • Integrates multi-sectoral data to model urban dynamics, enabling proactive decision-making and optimisation of city operations	• An open ecosystem that promotes innovation, co-creation and economic growth • It makes data accessible and enables city stakeholders to collaborate and develop interoperable, data-driven applications	• Proprietary, end-to-end systems that connect IoT devices, consume data, deliver insights and analytics for urban operations and enable smart use cases • By integrating IoT and analytics, these platforms help optimise resources (e.g., energy, water), while also providing the foundation for services across domains such as safety and mobility

4. Cognitive city operating systems: Unpacking the core building blocks

Navigating platform architectures: Constructing strategic choices

Key parameters	City intelligence platform	City data and integration platform	Vertically integrated urban operating systems
Key features	• **AI-powered decision support**: Uses machine learning, deep learning and generative AI to analyse patterns, forecast outcomes and recommend actions • **Digital twins and urban simulation**: Creates real-time and virtual replicas of city infrastructure, allowing planners to test scenarios and visualise impacts before implementation • **Real-time data integration**: Integrates multi-sectoral data streams, from mobility and energy to public safety and citizen feedback, into a unified intelligence layer • **Predictive analytics and optimisation**: Enables forecasting of traffic congestion, energy demand, emergency response needs and more, allowing for pre-emptive action • **Integrated command and control dashboards**: Provides leaders with a single pane of glass to monitor, manage and coordinate city-wide operations	• **Unified data cataloguing and marketplace tools**: Enables discovery, classification and sharing of datasets across city departments and external partners • **Real-time data subscription and alerting**: Allows stakeholders to subscribe to data streams and receive alerts based on predefined triggers or thresholds • **Open Application Programming Interfaces (APIs) and vendor-agnostic architecture**: Promotes interoperability and flexibility by supporting multi-vendor ecosystems and commonly available technology stacks • **Developer enablement and innovation Acceleration**: Provides software development kits, sandboxes and open data environments to support startups, small-to-medium enterprises and academic institutions in building urban applications • **Metadata governance and access control**: Ensures data quality, security and compliance through structured metadata management and role-based access policies	• **End-to-end IoT sensors and device management**: Enables full lifecycle management of connected devices, from deployment and monitoring to maintenance and upgrades • **Analytics for resource optimisation**: Provides real-time and historical insights to optimise consumption and performance across utilities like energy and water • **Integrations for seamless data flow**: Ensures smooth interoperability between devices, systems and platforms, enabling unified operations within the vertical • **Secure, real-time dashboards for operational monitoring**: Offers intuitive interfaces for city operators to monitor performance, respond to incidents and manage services in real time

4. Cognitive city operating systems: Unpacking the core building blocks

Navigating platform architectures: Constructing strategic choices

Key parameters	City intelligence platform	City data and integration platform	Vertically integrated urban operating systems
Key strengths	• **Enables proactive planning:** Leverages AI and predictive analytics to help city leaders anticipate challenges and allocate resources effectively • **Reduces operational bottlenecks**: Integrates real-time data and automation to streamline workflows and improve interdepartmental coordination • **Unifies siloed departments**: Establishes a shared intelligence layer that fosters collaboration and delivers unified, data-driven services • **Supports long-term urban planning**: Employs digital twins and simulations to test future scenarios and guide infrastructure, zoning and policy decisions	• **Promotes innovation and co-creation:** By opening data and providing developer-friendly tools, the platform fosters a vibrant ecosystem of urban innovators and solution providers • **Reduces vendor lock-in**: Its open architecture and public APIs allow cities to work with multiple vendors, avoiding dependency on proprietary systems • **Accelerates economic growth**: Enables data-driven entrepreneurship and job creation by making urban data accessible to startups, researchers and civic tech communities • **Supports scalable integration**: Acts as a flexible backbone that can evolve into more advanced intelligence platforms as the city's digital maturity increases	• **Seamless interoperability across components**: Integrates hardware, software and cloud infrastructure into a cohesive system, reducing implementation complexity and ensuring consistent performance • **Reduced implementation complexity**: Delivered and managed by a single vendor, the platform simplifies deployment, integration and ongoing operations across systems • **Built-in security and compliance**: Comes with pre-configured security protocols and compliance frameworks, reducing risk and accelerating time-to-value

4. Cognitive city operating systems: Unpacking the core building blocks

Navigating platform architectures: Constructing strategic choices

Key parameters	City intelligence platform	City data and integration platform	Vertically integrated urban operating systems
Examples	• **Hangzhou, China:** City brain system improves urban management by using big data, cloud computing and AI, among other cutting-edge technologies [11] • **Riyadh, Saudi Arabia:** Planning an integrated operations centre with a platform ("Smart C") that will consolidate and analyse data from relevant systems to generate actionable insights for stakeholders, enhancing citizen-centricity[12]	• **Barcelona, Spain:** Barcelona municipal government developed a unified data infrastructure that brings together disparate urban systems under a common architecture. Central to this is the open-source platform Sentilo, which was initiated to aggregate data from various sensors and systems. This infrastructure supports multiple domains, enabling city administrators to deploy integrated dashboards and analytics rather than isolated solutions[13]	• **Amsterdam, Netherlands:** Known for its mobility-focused platforms, Amsterdam has deployed integrated systems for traffic flow optimisation, smart parking and public transport coordination[14] • **Seoul, South Korea:** Seoul has implemented vertically integrated platforms for public safety, combining surveillance, emergency response and predictive analytics into a unified system[15]

4 Cognitive city operating systems: Unpacking the core building blocks

b. Embarking on the cognitive journey: Key considerations

Choosing the right cognitive city operating system is a critical foundation, but it is only the beginning of the journey. To unlock the full potential of a resilient and intelligent city, city leaders must look beyond the platform itself and cultivate the broader ecosystem required to sustain its success. This includes strong governance structures, strategic partnerships, ethical frameworks, skilled talent and active citizen engagement. Without these enablers, even the most advanced platform risks being underutilised or misaligned with city priorities.

A cognitive city operating system must be embedded within a well-orchestrated urban framework – agile enough to adapt to change, inclusive in serving diverse communities, secure against emerging threats and ready to anticipate future challenges and opportunities. The following considerations are essential for building the cities of the future. .

- **Ecosystem collaboration and partnerships:** Cities thrive when collaboration evolves from transactional vendor deals into orchestrated ecosystems. Leaders should engage technology providers, academia, startups and open-source communities to co-create solutions and accelerate innovation. Aligning partners, service integrators and vendors around shared governance, vision and interoperability ensures lasting alignment and collective impact

- **AI ethics and responsible intelligence:** As AI becomes central to city operations, responsible practices are vital to sustain trust. Frameworks must go beyond compliance, embedding fairness, transparency and accountability through bias mitigation, algorithmic explainability and citizen consent. In future cities, trust will be the cornerstone and ethical AI the foundation of legitimate digital governance

- **Cybersecurity and data privacy:** A cognitive city's resilience depends on protecting systems and data. Cities must enforce cybersecurity, privacy and incident response protocols. Compliance with global standards and safeguarding citizen data are non-negotiable to maintain trust and protect the integrity of the urban ecosystem

- **Talent and capability building:** Technology delivers only through people. Cities must invest in continuous upskilling, attract top digital talent and foster innovation-led cultures. Training programmes, digital academies and knowledge-sharing platforms reduce vendor dependency and empower a new generation of cognitive city leaders to evolve the city's digital core

- **Funding and business models:** Sustaining a cognitive city demands diverse, long-term funding. Cities should blend public investment, partnerships, donor support and monetised digital services to build resilience. Clear business models and transparent governance ensure continuity, scalability and measurable value for all stakeholders

- **Citizen engagement and inclusion:** Cities must be inclusive by design, embedding citizen engagement through participatory planning, real-time feedback and intuitive digital platforms. Accessibility, multilingual interfaces and equity-focused service delivery ensure solutions remain relevant, trusted and available to all – leaving no group behind in the digital transformation

5. Translating vision into action

The transformation toward a cognitive city is far more than a technology initiative; it is a profound societal evolution. It reimagines how cities sense, think and act in service of their citizens. This shift calls for visionary leadership to look beyond infrastructure, platforms and data to see cities as living, learning systems that continuously adapt and evolve. Building such cities demands deep collaboration between policymakers, technologists, investors and innovators all united by a shared purpose of creating urban environments that are not only smart, but truly cognitive that anticipate needs, respond in real time and grow intelligently with their people.

Establish a unified city data fabric

The first imperative is to create a trusted and interoperable data foundation that consolidates information across departments, sectors and systems. City authorities and technology leaders should collaborate to design a federated data model that promotes secure data sharing while preserving sovereignty and compliance with national and local data regulations. This approach can unlock cross-agency insights, enable AI-driven decision-making and break down the silos that currently limit urban innovation and responsiveness.

5. Translating vision into action

Co-develop a cognitive city operating framework

Governments and private sector partners should work together to further develop the idea of cognitive city operating system, shaping its conceptual foundations and operational contours for the future and define a governance and operating framework for the cognitive city operating system that harmonises technology, policy and citizen outcomes. This framework can help define and establish the foundational building blocks of the cognitive city operating system enabling multiple city domains to interact intelligently and cohesively. Establishing a joint steering committee and bringing together leaders from both public and private sectors would help sustain long-term alignment, transparency and accountability across the city ecosystem.

Champion citizen-centric experience design

Cognitive cities should be designed around living experiences and evolving needs of their people. City authorities are encouraged to embed citizen engagement mechanisms within the operating system layer to ensure that services remain adaptive, responsive and aligned with community priorities. Technology providers can reinforce these efforts by integrating behavioural insights and personalisation capabilities that make urban services more intuitive, inclusive and accessible to all.

Accelerate digital infrastructure modernisation

City leaders and hyperscalers should focus on modernising legacy infrastructure to develop cloud-native, edge-ready platforms capable of managing vast data flows and enabling real-time analytics. Prioritising investments in scalable, energy-efficient digital infrastructure and next-generation connectivity will be essential to drive this transformation. Progress can be accelerated through policy incentives, PPPs and shared investment models that reduce the cost of innovation and making modernisation more attainable for districts and municipalities.

Foster cross-ecosystem collaboration

No single entity can build a cognitive city in isolation. The future of urban intelligence depends on a vibrant ecosystem where governments, academia, hyperscalers, startups and civic organisations collaborate to co-create digital solutions that share data responsibly and scale innovation sustainably. By establishing urban innovation sandboxes and co-investment programs, stakeholders can accelerate the development and deployment of AI-driven city services turning bold ideas into transformative outcomes while managing risk through structured real-world experimentation.

5. Translating vision into action

Embed cybersecurity and ethical AI governance

As cognitive cities become increasingly dependent on emerging technologies, cyber resilience and ethical AI governance must serve as foundational pillars of trust. City leaders should champion the adoption of zero-trust architectures, AI transparency frameworks and continuous threat monitoring to safeguard critical infrastructure. At the same time, policymakers are encouraged to embed ethical AI principles within urban governance charters ensuring privacy, fairness and accountability are upheld while fostering public confidence and investor trust in the digital foundations of cities.

Drive sustainable and resilient urban outcomes

A cognitive city operating system should place sustainability at its very core, not as a parallel goal but as a guiding principle for every decision and investment. City leaders can harness AI-driven analytics to optimise resource consumption, minimise emissions and strengthen climate resilience across urban systems. Governments and private sector partners are encouraged to co-create cognitive sustainability indexes that track progress toward net-zero ambitions and measure improvements in liveability ensuring that each technological advancement contributes to enduring economic, social and environmental value.

6. The future of cities: Unified cognitive intelligence

As cities face rapid urbanisation, climate urgency and rising citizen expectations, progress can no longer be incremental. The path forward demands a shift from fragmented initiatives to a cognitive city operating system that unifies intelligence, orchestrates ecosystems and puts people at the centre of transformation. This approach redefines how cities think, respond and evolve in real time.

The true promise of a cognitive city operating system lies not only in technology alone but in its power to build trust, inclusivity and resilience. Embedding ethical AI, strong governance and transparent standards into the digital core enables cities to create environments where citizens feel empowered, businesses thrive and governments lead with legitimacy.

The journey ahead demands vision, collaboration and sustained commitment from city leaders, technology providers, academia and civil society to co-create adaptive, interoperable and citizen-centric ecosystems. By embracing the cognitive city operating system as the unifying digital fabric of urban life, cities can move beyond siloed solutions to unlock transformative value and deliver a higher quality of life for all.

The future of cities will not be defined by technology alone but by how purposefully it is orchestrated. The cognitive city operating system is the catalyst for this future – where cities are not just smart but truly cognitive, responsive and human-centred.

Sources

1   World Bank Group, "Urban Development". Available here.

2   Envac Group, "Barcelona's envac system is being modernised". Available here.

3   VodafoneThree, "Vodafone-led consortium to deliver next phase of air quality monitoring network across London". Available here.

4   Digi, "12 Real-World Examples of How the IoT Monitors Vehicle Traffic". Available here.

5   Smart Cities World, "Seoul implements intelligent disaster prevention system". Available here.

6   GovTech Singapore, "How is Singapore building its digital twin? Virtual Singapore creates a data-rich 3D model for smarter urban planning and real-time simulations.". Available here.

7   The Times of India, "Govt uses LiDAR tech to predict flood risks and facilitate relief ops in Kashi". Available here.

8   Amsterdam Smart City, "CityFlows, Innovating Crowd Management Practice". Available here.

9   Implementing the new urban agenda, "Rio Operations Center: Integrating data and monitoring utilities in a truly intelligent system". Available here.

10 O. M. Prabowo, E. Mulyana, I. G. B. B. Nugraha and S. H. Supangkat, "Cognitive City Platform as Digital Public Infrastructure for Developing a Smart, Sustainable and Resilient City in Indonesia," in IEEE Access, vol. 11, pp. 120157-120178, 2023, doi: 10.1109/ACCESS.2023.3327305. Available here.

11 eHangzhou, "Hangzhou launches City Brain 3.0, advancing smart governance". Available here.

12 Saudi Press Agency, "SDAIA Showcases Smart C National Platform, Smart City Algorithms in Davos". Available here.

13 Barcelona Digital City, "Sentilo, the Barcelona Sensors Network". Available here.

14 Amsterdam Smart City, "Smart traffic management, reduce traffic by implementing smart systems". Available here.

15 Seoul Metropolitan Government, "Smart Public Safety, Building an AI-powered citywide surveillance camera network". Available here.

Authors

Contributors

Hazem Galal

Global Cities & Local Government Leader and Global Smart Mobility Co-Leader, PwC Middle East
hazem.galal@pwc.com
https://www.linkedin.com/in/hazemgalal/

Rajat Chowdhary

Partner, Technology Consulting,
PwC Middle East
rajat.c.chowdhary@pwc.com
https://www.linkedin.com/in/rajatchowdhary/

Sameer Gupta

Manager, Technology Consulting, PwC Middle East
sameer.a.gupta@pwc.com
https://www.linkedin.com/in/sameer14/

Varun Paul

Partner, Technology Consulting,
PwC Middle East
varun.p.paul@pwc.com
https://www.linkedin.com/in/paulvarun/

Mohammed Arbaz Ansari

Senior Manager, Technology Consulting, PwC Middle East
mohammed.arbaz.ansari@pwc.com
https://www.linkedin.com/in/arbazansari/

Azaan Bin Adnan Khan

Senior Associate, Technology Consulting, PwC Middle East

azaan.k.khan@pwc.com
linkedin.com/in/azaank

pwc.com