How interoperability can safeguard our future cities

CitiesToday Studio

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Why interoperability is the foundation for digital cities

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Cities run on data. Every streetlight, traffic sensor, meter, and public service generates information that could make urban life safer, cleaner, and more efficient. Yet much of that potential is lost because these systems rarely talk to each other. Built by different suppliers with incompatible data models, they create costly silos that block innovation.

Interoperability is the ability of a device or system built by one supplier to dialogue with a system or device built by another, without being locked into a single ecosystem. This interoperability comes from the adoption of recognised industry standards as far as data models and communication protocols are concerned and provides systems with a shared digital language.

Interoperability ensures that devices, platforms, and services can communicate seamlessly, regardless of manufacturer or use case. This is not just a technical goal but a strategic one: cities that adopt open standards can evolve with new technologies instead of being trapped in legacy systems.

Seth Newberry, Executive Director at the Open Mobile Alliance (OMA), which sets global standards for mobile and IoT interoperability, says this openness is essential for sustainable progress.“Open data models deliver three core benefits: future-

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Julia Arneri Borghese, CEO, Paradox Engineering

proofing investments, lower integration costs, and vendor diversity and innovation," he says.

For 20 years, Paradox Engineering has been designing the principles of interoperability into practice. The company specialises on the design and engineering of IoT technologies for smart environments and has been part of MinebeaMitsumi Group since 2015.

It provides open, scalable systems that enable cities and utilities to manage lighting, parking, and other services through a single, integrated infrastructure.

Julia Arneri Borghese, CEO at Paradox Engineering, explains the company's strategic choice.

"We recognise that interoperability is the foundation for creating scalable, future-proof solutions for cities. By focusing on standard-based systems, we ensure that our solutions dialogue with existing and future technologies, allowing cities to maximise the value of their investments over time."

At the heart of this approach is a commitment to open standards. Paradox Engineering is an active member of the uCIFI Alliance (now a part of OMA), a global coalition of cities, utilities, and technology companies that develops and promotes standardised IoT data models for smart urban applications.

Paradox Engineering contributed to the development of the uCIFI Data Model–the first open, vendor-neutral framework designed for cities and utilities–and is now actively engaged in OMA's Smart City Working Group. The data model provides a common structure for describing and managing connected equipment across more than 30 categories of devices, from streetlights and sensors to meters and controllers.

This alignment between OMA's communication protocol and uCIFI's data model gives cities the freedom to integrate devices from different suppliers into a single network. Instead of being locked into proprietary systems, municipalities can expand or upgrade their infrastructure without costly custom integrations or loss of compatibility.

"While cities are generally aware of their present needs, they often face difficulties in predicting next challenges and evolving technologies," Arneri Borghese says. "Products and systems designed to be interoperable through recognised standards are a long term choice that offer the chance to adapt to new scenarios and opportunities, whether they relate to climate change, population growth, economic shifts, or other issues."

This philosophy underpins Paradox Engineering's work with cities worldwide. Its urban IoT networks are designed around open

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Seth Newberry, Executive Director at the Open Mobile Alliance

protocols, standard APIs, and transparent governance, allowing them to evolve as technologies and policies change. Interoperability is not treated as an optional feature.

Newberry at the Open Mobile Alliance emphasises that standards do not stifle innovation, they enable it.

"Standards do take time, but they are an organised means to get real-world requirements for critical tasks, and they improve the odds of broad adoption of the core technology," he says. "OMA's initiatives show that standards provide the foundation upon which vendors can innovate, focusing on higher-value features instead of reinventing the basics."

By aligning data definitions, communication protocols, and testing processes, OMA and its partners ensure that new technologies can enter the market without undermining existing infrastructure. Cities can therefore focus resources on service delivery and innovation rather than integration and maintenance.

Paradox Engineering applies the same approach to interoperability in its product design and city partnerships. Each new deployment builds on the same open architecture, ensuring that data flows freely between applications and that lessons learned in one city can be reused in another.

This approach supports what Arneri Borghese calls "interoperability as governance": a model where technology decisions protect public investment while fostering collaboration and transparency.

Why interoperability matters

Ultimately, interoperability is about trust and adaptability. Open standards make innovation cumulative rather than isolated. Each new system strengthens the overall digital foundation instead of creating another silo.

As Newberry summarises: "Cities bring the needs, vendors bring the products, alliances bring the frameworks–OMA makes them all work together."

This collaborative model ensures that technology investments remain future-ready and publicly accountable. The result is a continuous process of improvement – one where cities can evolve sustainably, suppliers can compete fairly, and citizens benefit from systems that are connected, transparent, and built to last.

How to build the foundations of openness

Credit: © Paradox Engineering

The promise of connected cities depends on a simple idea: every device, system, and service should be able to communicate through a shared language. For Paradox Engineering and its partners, achieving that vision begins with the data model–the foundation that gives structure and meaning to communication across connected infrastructure.

“Our architecture is built on client/server objects running over a standard transport protocol,” says Newberry. “The objects define the behaviour of the thing being measured or controlled and the transport carries the information securely and efficiently across a fault-tolerant network. Cities can add custom objects or attributes without breaking interoperability, giving them the flexibility to reflect local regulations or infrastructure practices.”

This layered approach–global core plus local extensions–balances consistency with adaptability. It ensures that local requirements don’t become barriers to adopting globally recognised frameworks.

Matteo Semmoloni, Head of Solution Design at Paradox Engineering, explains: “We design the key features of our products according to uCIFI Data Model and OMA specifications, so they are interoperable by design.”

The standardisation of the data model enables smooth communication and integration between systems while enhancing data integrity, minimising inconsistencies, and optimising data quality.

Arneri Borghese underlines the civic value of this flexibility. “Interoperable infrastructure gives cities the flexibility to extend the network over time, add new applications and evolve present services gradually, as change becomes necessary and feasible.”

The result is not just technical efficiency but long-term resilience. Interoperability allows governments to upgrade components without rebuilding entire systems and to integrate emerging technologies and products.

Through its no-fee membership programmes, OMA invites municipalities and universities to participate directly in the specification process. Real-world operational requirements from cities feed into the standards themselves, ensuring that the resulting frameworks are both technically robust and practically applicable.

Paradox Engineering channels those same standards into deployable solutions. The company is actively engaged in OMA’s Smart City Working group, bridging the gap between abstract specifications and field-tested systems. This synergy means that what is agreed in standards.

Semmoloni stresses that real-world success depends on implementation discipline.

"We deliver interoperability at two levels. First is the data model: its standardisation enables smooth communication and integration between systems while enhancing data integrity, minimising inconsistencies, and optimising data quality. Second level is about the network to ensure that our devices can be monitored and controlled remotely either from our central management software, or from third-party platforms."

APIs are thus essential as standardised interfaces for data exchange and system interactions. When APIs are effectively implemented, platforms can grow and scale seamlessly, even across multiple domains.

He points to the company's latest Hybrid Zhaga and Cellular Zhaga lighting nodes as examples.

"They fit any street and outdoor lamp equipped with a Zhaga socket, feature a standard data model and allow the customer to select its preferred remote management platform," he says.

Such flexibility exemplifies how open standards empower cities to make independent, long-term decisions without jeopardising compatibility or performance.

Overcoming barriers

Moving to true interoperability means dealing with legacy systems and data silos. Many municipal infrastructures combine decades-old assets with new digital layers, creating mismatched formats and protocols.

"One of the primary issues is data incompatibility, as many customers use proprietary systems generating data in different formats," Semmoloni says. "When data models and protocols vary, it's like trying to communicate in different languages: integration becomes complex and resource-consuming."

Integrating legacy systems with new interoperable platforms often requires developing custom interfaces and may introduce significant complexity and additional costs to projects.

"It's a challenging process, but one that is necessary if customers need to bridge the gap between their previous and new technology choices," adds Semmoloni.

The company's experience suggests that upfront investment in open standards pays off by reducing long-term costs and avoiding vendor dependency.

Arneri Borghese notes that while proprietary systems may appear cheaper initially, they are rarely sustainable.

"Independent studies have shown that smart-city projects using proprietary technologies can cost up to 30 percent more than those

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Matteo Semmoloni, Head of Solution Design at Paradox Engineering

How the LwM2M standard helps cities

Lightweight M2M (LwM2M) is a communication protocol that provides a common framework for how IoT devices are described, configured, and monitored. It defines a standard way for devices–such as sensors, meters, or controllers–to exchange data securely and efficiently with management systems, regardless of manufacturer or use case.

Operating on top of existing internet technologies, LwM2M is particularly suited to large-scale, resource-constrained environments such as cities and utilities. It ensures that every device follows the same structure when reporting data or receiving commands, enabling thousands of devices to work together across a unified network.

"Our LwM2M standard, combined with the uCIFI data model, provides a common language for constrained IoT devices and smart infrastructure," says OMA's Seth Newberry. "By harmonising how devices report data and are managed remotely, OMA reduces the need for custom integrations and ensures that equipment from multiple vendors can coexist in the same deployment."

In essence:

- LwM2M = the communication and management layer (how devices talk and are controlled)
- uCIFI = the data model layer (what devices are and how their data is structured)

Together, they form the foundation of open, interoperable IoT systems for cities.

based on open technologies, due to increased complexity, duplicated implementation and maintenance efforts, and a higher risk of obsolescence."

Security and governance

Interoperability must also coexist with rigorous security and privacy protection. Semmoloni explains that these goals are complementary rather than conflicting.

"Granting high security standards doesn't mean hiding data or building defensive walls, but having a holistic view of infrastructure and network protection," he says. "Our approach is a mix of secure-by-design technology, adopting state-of-the-art measures to offer intrinsically secure systems, processes to identify and mitigate vulnerabilities, and educating people, as awareness and preparedness are the first line of defence when security and privacy are at stake both at development and customer levels."

This approach reflects the maturity of open-standard ecosystems with security embedded in the protocol itself rather than bolted on afterwards. OMA's specifications follow the same principle, ensuring that every connected device operates within a secure, authenticated framework.

Towards resilient infrastructure

Together, these elements–standard data models, open APIs, multi-vendor networks, and built-in security–form the practical foundation of openness. They transform interoperability from a policy statement into an operational reality.

Newberry agrees that cities adopting shared standards today will be best positioned for tomorrow's innovations.

"OMA has been developing homologated specifications for years," he says. "We provide a global baseline through LwM2M and the uCIFI models while allowing for local extensions or optional features."

By embedding interoperability in design, governance, and procurement, cities can build infrastructures that can benefit from technological change rather than be replaced by it.

Open by design: the interoperability advantage

Interoperability is often described in technical terms but its value is ultimately civic. Openness gives cities the ability to evolve, learn, and share knowledge across borders, ensuring that innovation benefits everyone, not just those tied to specific vendors or systems.

Arneri Borghese highlights that the next opportunities lie in the seamless integration of diverse urban applications.

"Think of smart lighting: if backed by an interoperable network, it goes beyond street illumination and becomes the perfect platform to support smart mobility initiatives, environmental monitoring and climate adaptation strategies, and emergency response systems."

That resilience depends on two things: technical design and institutional will. Even the most open data model is ineffective if cities cannot align their internal systems or share data across departments.

A layered architecture for adaptability

The concept of 'open by design' extends far beyond connectivity. Openness must be embedded across every layer of the system–from device firmware to data management and civic governance.

"We ensure long-term compatibility by continuously upgrading our products to reflect changes in industry standards," explains Semmoloni. "We also contribute to the evolution of standards to ensure they meet the emerging needs of cities and utilities."

Openness should be the default state of the network rather than a special feature. By aligning communication protocols and data models, these organisations enable any compliant device to join a shared urban platform with minimal configuration.

Madrid's path to coordination and trust

Interoperability is not achieved through technology alone–it also demands political commitment and administrative coordination. Cities must reconcile different procurement cycles, departmental silos, and regulatory requirements.

This is the experience of Madrid, whose work on digital transformation shows that achieving interoperability is as much about mindset as it is about technology.

The city has long operated a range of intelligent systems across departments–traffic management, lighting, waste, and environment–all procured and developed at different times and often with different technical standards. Unifying those systems into a single framework has required patience, coordination, and a shared vision of what openness means.

Juan Jesús Muñoz Esteban, Head of Service for 5G and IoT at Madrid City Council, says the starting point was recognising the fragmentation created by multiple, overlapping frameworks.

"The lack of standards in IoT, or rather the excess of supposed standards has complicated integration and slowed progress," he says.

Las Condes, Santiago – interoperability in action

The municipality of Las Condes in Santiago, Chile, began its smart-city journey in 2018 by implementing an interoperable wireless IoT network for street lighting. Over time, the network expanded to connect more than 17,000 streetlights and integrate parking management, traffic surveillance, air-quality monitoring, and environmental sensors.

"The interoperability of this system allowed for all urban objects and data to be collected through a single network and monitored via a centralised software platform, showcasing how interoperability drives both cost-efficiency and growth," comments Semmoloni.

The example from Las Condes demonstrates how an open foundation supports continuous expansion. Instead of deploying multiple proprietary networks, the muncipality was able to extend one infrastructure to accommodate new services–reducing costs, simplifying management, and improving overall transparency.

He notes that this resistance is not only technical but institutional, with independence valued as the ability to solve one's own problems without depending on third parties who may have other priorities in times of crisis.

The challenge is not simply to connect technologies but to align cultures and expectations across teams accustomed to working autonomously. Madrid's approach has focused on balancing innovation with stability–adopting open standards while safeguarding essential services.

"For a large public administration, protecting investment is essential: a large city cannot be radically changed, either in terms of cost or time," Muñoz Esteban explains. "Any evolution involves the coexistence of different solutions over time. As standards become established, the transformation can be gradual and without abrupt changes."

He compares this to how technology evolves in everyday life. "Just look at how long it took for smartphones to replace traditional phones, which were functionally incomparable, and how in recent years the new versions coexist with the previous ones. Or how difficult it is to switch from fossil fuel vehicles to electric ones, which require energy infrastructures that take time to deploy."

The same logic, he argues, applies to public–private collaboration. "Creating a standard requires considerable effort and time. It requires a volume of business that justifies it," he says. "Innovation,

on the other hand, has shorter deadlines and can jeopardise the continuity of a company. The commitment of companies to public service deadlines and the protection of investment is essential, because alignment is needed for companies to maintain their activity and for administrations to evolve. That is why it is essential for both parties to share the same vision of the market and its evolution."

Madrid's experience demonstrates that interoperability not only depends on technology but also a process of governance and coordination that takes shape over time. The city's approach aligns closely with the broader frameworks advanced by OMA, uCIFI, and their partners: gradual integration, open standards, and shared responsibility between administrations and industry. In practice, this means building systems that can grow without breaking, evolve without losing continuity, and serve citizens through flexibility rather than fragmentation.

Institutional and market alignment

Madrid's experience shows that cities and companies must evolve together. For Paradox Engineering, this collaboration requires shared commitment to open standards that protect both innovation and long-term investment.

"It's about creating synergies that drive both innovation and standardisation, competition and cooperation," says Arneri Borghese.

This alignment of interests is what gives interoperability its staying power. When public and private sectors operate under the same open frameworks, cities gain stability, vendors gain market reach, and citizens benefit from transparent, adaptive systems.

The civic dividend of openness

Choosing interoperable and standard based systems is not a back-end concern but a measure of civic maturity. It ensures that technology investments remain future-ready and publicly accountable. Open standards make innovation a continuous process where each new service strengthens, rather than fragments, the city's digital foundation.

In this sense, being open by design is about more than data–it is about governance, trust, and longevity. As cities such as Madrid and Las Condes have shown, openness transforms urban technology from a collection of systems into a living ecosystem, built to evolve over time and to serve people first.

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Juan Jesús Muñoz Esteban, Head of Service for 5G and IoT, Madrid City Council

From isolation to integration

As cities evolve, so does the meaning of interoperability. What once referred to the technical ability of devices to communicate with each other now encompasses how governments, institutions, and businesses collaborate through shared data and standards. Openness has become the measure of whether a city's digital transformation is sustainable, inclusive, and resilient.

Newberry, from OMA, notes that the organisation's experience with global communications networks provides a model for this next phase.

"OMA has a long history of enabling massive-scale interoperability. Our OMA Device Management specification–the precursor to LwM2M–is deployed in virtually every mobile phone worldwide, giving us unique experience in creating technologies that remain relevant and sustainable over decades."

Building on that foundation, OMA's members are now developing specifications for the convergence of IoT, AI, and digital twins. These emerging systems depend on the same consistency and trust that made the first generation of connected infrastructure possible.

"With LwM2M, our members have designed objects and protocol characteristics that deliver exactly what smart cities and utilities require: fault-tolerant connections, efficient use of bandwidth, extended battery life for constrained devices, and the ability to scale from thousands to millions of endpoints," he says.

For Paradox Engineering, this evolution reinforces its long-standing philosophy of designing systems that can adapt over decades, not years. Semmoloni explains that open standards ensure cities can embrace new digital tools without discarding existing investments.

"The standardisation of the data model enables smooth communication and integration between systems while enhancing data integrity, minimising inconsistencies, and optimising data quality," he says.

As cities experiment with digital twins, predictive analytics, and AI-enabled services, interoperability will determine whether these tools deliver insight or chaos. Open frameworks like LwM2M and uCIFI provide the shared semantics that keep data meaningful and comparable, ensuring that cities remain in control of their infrastructure and information.

Arneri Borghese argues that this is ultimately a question of governance. "We firmly believe that innovation and open standards go hand in hand. This means building solutions that are compliant with open protocols, support cross-platform integration, and can easily scale across different urban systems."

By embedding openness in procurement, policy, and design, cities can shift from managing isolated projects to orchestrating living systems that evolve continuously to meet public needs.

Interoperability is both a safeguard and a strategy. It ensures that technological progress aligns with civic goals, that data remains a shared public asset, and that innovation strengthens rather than fragments urban life. Through shared standards and collective responsibility, cities can transform their digital landscapes into connected, adaptive ecosystems that serve citizens better today and in the future.