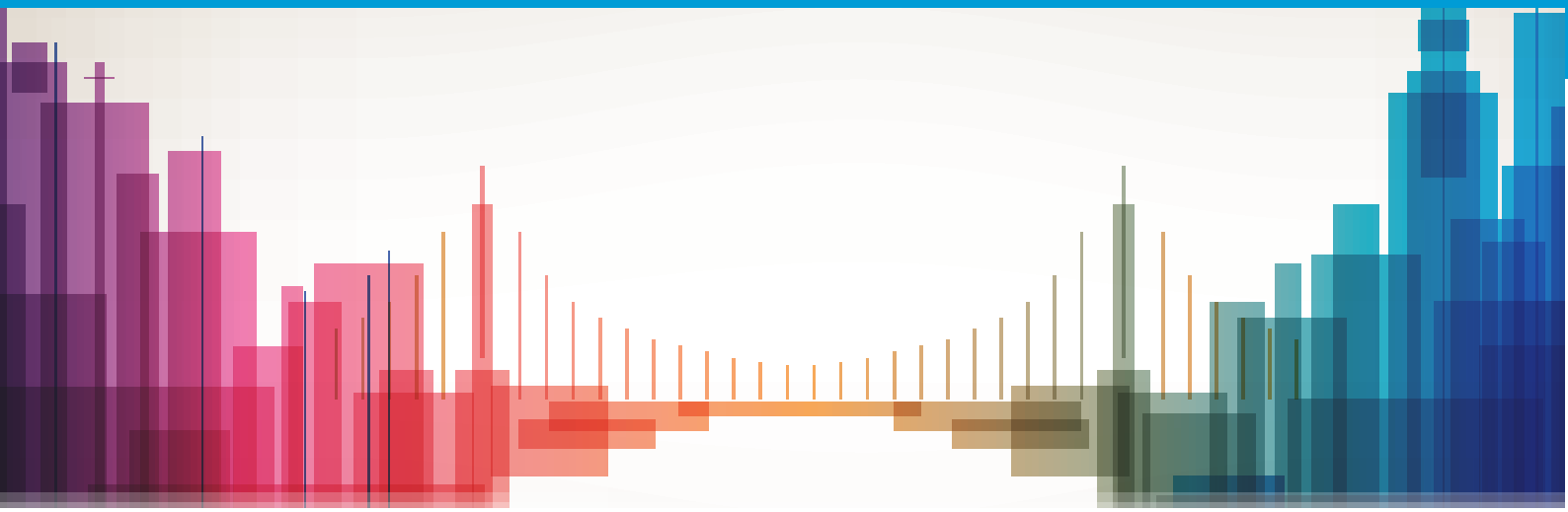
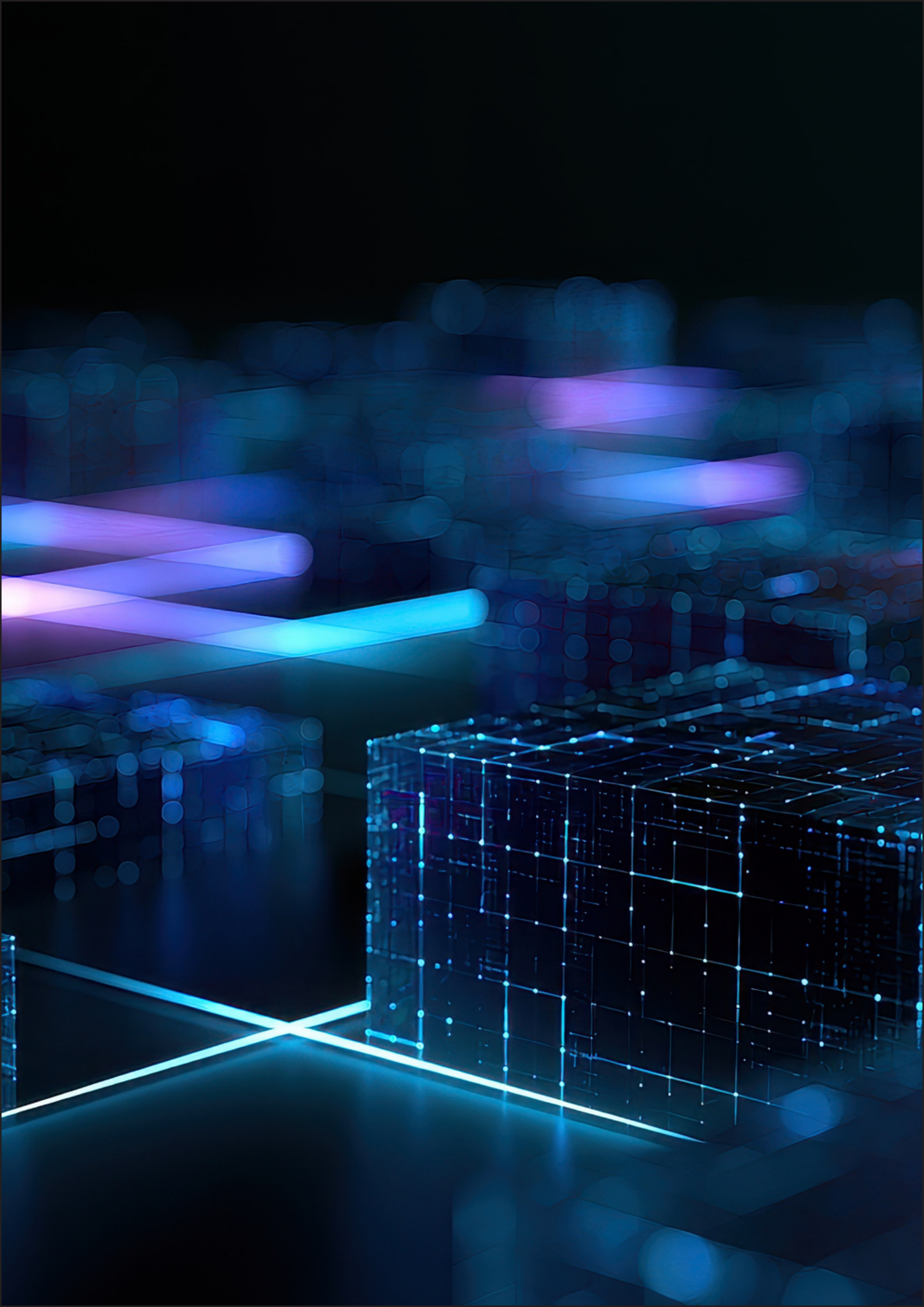
Connecting smart city platforms and data spaces: The strategic role of data offices







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Foreword

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Disclaimer

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Abbreviations and acronyms

Abbreviation	Full form
ABM	Agent-based model
AI	Artificial intelligence
API	Application programming interface
BMS	Building management system
CDO	Chief Data Officer
DAPS	Dynamic Attribute Provisioning Service
DCAT-AP	Data Catalogue Vocabulary – Application Profile
DGA	Data Governance Act
DID	Decentralized identifier
DLT	Distributed ledger technology
DO	Data Office
DPO	Data Protection Officer
DS	Data Space
DSBA	Data Spaces Business Alliance
EDC	Eclipse Dataspace Connector/Eclipse Dataspace Components
ENS	National Security Framework
ETSI CIM	European Telecommunications Standards Institute Context Information Management
FIWARE	Open-source platform for smart solutions and data management
FNMT	Spanish National Mint
GDPR	General Data Protection Regulation
GIS	Geographic information system
GTFS	General Transit Feed Specification
HTTPS	Hypertext Transfer Protocol Secure
IAM	Identity and access management
ICT	Information and communication technology
ICTs	Information and communication technologies
IDS	International Data Spaces
IDSA	International Data Spaces Association
IdP	Identity Provider
IoT	Internet of things
ISO	International Organization for Standardization
ITU	International Telecommunication Union
LED	Light-emitting diode
LEZ	Low Emission Zone
MIMs	Minimum Interoperability Mechanisms
ML	Machine learning
MoD	Mobility on Demand

Abbreviation	Full form
MPC	Model Predictive Control
MQTT	Message Queuing Telemetry Transport
NGSI	Next Generation Service Interfaces
OASC	Open & Agile Smart Cities
ODRL	Open Digital Rights Language
OIDC	OpenID Connect
OPC UA	Open Platform Communications Unified Architecture
PEP	Policy Enforcement Point
PETs	Privacy-enhancing technologies
PGOU	General Urban Development Plan
SME	Small and medium-sized enterprise
TLS	Transport Layer Security
U4SSC	United for Smart Sustainable Cities
UDS	Urban Data Space
VC	Verifiable Credential
W3C	World Wide Web Consortium

Executive Summary

Cities are accumulating data faster than they are developing the capacity to govern and use it effectively. Sensors, mobility systems, utility networks, public services, and citizen interactions generate information of considerable value; and yet much of that value remains unrealized. Data are often fragmented across departmental and organizational silos, described using incompatible standards, and controlled by multiple actors – including municipal departments, utilities, concessionaires, private operators, and national or regional authorities – with no common framework for exchanging and using it. The principal challenge is, therefore, not uniquely technological; it is also organizational, institutional, and governance related.

This deliverable examines how city platforms, data spaces, and Data Offices can address this challenge. It defines city platforms and data spaces, explains how they differ from conventional municipal data platforms, and describes how cities can progressively connect their internal data environments to broader collaborative ecosystems. Its central argument is that integration is a governance challenge before it is an architectural one. Technical interoperability enables data exchange; but sustainable data sharing depends on participants trusting the rules under which data are accessed, used, protected and governed.

A city platform provides the technical and operational foundation for integrating data and services within the urban environment. A data space extends this model by enabling controlled and trusted data exchange among independent organizations while preserving governance, sovereignty, and usage conditions. Consequently, the transition from one to the other involves more than deploying connectors or adopting common technical standards. It requires cities to determine which data they control, who is accountable for these data, under what conditions these data may be shared, and how external organizations can participate.

The Data Office (DO) provides the organizational capacity needed to manage this transition. It should be understood not necessarily as a fixed administrative unit, but as a set of strategic, governance, operational, and ecosystem-facing functions. These include defining the city's data strategy; establishing data governance, classification, quality, and usage policies; coordinating semantic and technical interoperability; supporting regulatory and ethical compliance; and managing relationships with external participants in the data ecosystem.

These functions require clearly differentiated responsibilities. The Chief Data Officer (CDO) provides strategic leadership and accountability for the city's data strategy and governance framework. Data Owners remain accountable for data within their respective areas and determine classification, access, and business requirements. Data Stewards manage definitions, quality, and operational governance, while Data Custodians operate the technical environments in which data are stored, accessed, and exchanged. These functions must also remain distinct from statutory roles such as the Data Protection Officer (DPO), whose independence and compliance responsibilities should not be confused with the Data Office's broader mandate to enable responsible data use and sharing.

The Data Office model must nevertheless be proportionate to municipal capacity. Not every city requires or can sustain a fully staffed dedicated office. Smaller and medium-sized municipalities can establish these functions progressively, beginning with a named accountable officer, a data inventory, and basic governance procedures. They may also rely on shared or federated arrangements operated by associations of municipalities, regional authorities, or national institutions. What matters is that the required functions and responsibilities are fulfilled, rather than that every municipality adopts the same organizational structure.

Institutional context is equally important. The data required for urban management are not always produced or controlled by municipalities. National and regional agencies, utilities, transport operators, telecommunications providers, and other organizations may control critical datasets or infrastructure. Cities should, therefore, map data ownership, institutional authority and intergovernmental responsibilities before designing their technical architecture. The appropriate governance model will differ across centralized, federal, decentralized, and hybrid administrative systems.

For the same reason, this deliverable proposes an adaptive rather than prescriptive framework. Municipal authority, service delivery models, data ownership, regulatory responsibilities and institutional capacity vary substantially across jurisdictions. The objectives – interoperability, sustainability, transparency, security, public value, and citizen-centred services – may be broadly shared, but the institutional arrangements used to achieve them cannot be universal. References to specific regulatory frameworks, standards or initiatives should, therefore, be understood as examples that must be adapted to the applicable jurisdiction.

Participation by external actors is another essential component. A technically functional data space has limited value if organizations have no reason or ability to participate. Cities should establish a trust and participation framework defining who may join, applicable certification or conformity requirements, data usage and onward-sharing conditions, liability and dispute-resolution mechanisms, and the incentives for participation. These conditions will often need to be negotiated with utilities, transport operators, telecommunications providers, businesses, research organizations, and other public authorities, and may differ according to the type of participant.

Governance must also extend to the responsible use of data and emerging technologies. Where artificial intelligence or other analytical models inform municipal decisions, governance should cover not only the underlying data but also the systems that use it. Relevant responsibilities include maintaining an inventory of models and their purposes, assessing risk, documenting data provenance, evaluating potential discriminatory effects, and ensuring appropriate human accountability. Data protection, cybersecurity, ethical use, inclusion, and a "do no harm" principle should be treated as design requirements from the outset rather than as compliance checks applied after deployment.

For city managers, the recommended path is, therefore, progressive. Cities should first assess their existing data and institutional environment, identifying available datasets, responsibilities, information silos, quality problems, and interoperability barriers. They should then define a

data strategy based on urban outcomes, establish the minimum governance and organizational framework needed to implement it, and develop common foundations for interoperability.

Rather than attempting comprehensive integration from the outset, cities should then demonstrate value through one or a small number of high-impact use cases with measurable operational, economic, environmental or social benefits. Early results provide evidence for subsequent investment, help refine governance arrangements, and strengthen the case for external financing where municipal resources are limited. Further use cases, infrastructure, and organizational capabilities can then be added progressively, reusing what has already been established.

Participation in wider sectoral, regional, national, or international data spaces should follow as organizational maturity increases. A city is better positioned to exchange data externally once it understands which data it holds, who is responsible for this, what quality and interoperability requirements apply, and under what conditions the data can be shared.

The transition toward urban data spaces should, therefore, not be understood as a single technology project. It is a gradual transformation in how cities govern, organize, share, and derive value from data. The practical principle is straightforward: understand the starting point, define the purpose, establish governance, demonstrate value, learn from implementation, and scale progressively. Technology enables this process, but clear responsibilities, trusted rules, institutional cooperation, and sustained organizational capacity are what make it viable.


FUTURE STATE ENTERPRISE A
BUSINESS
DIGITAL ENGAGEMENT
CUSTOMER MANAGEMENT
ORDER MANAGEMENT
Customer Centric
Agile Delivery
APPLICATION
EXPERIENCE LAYER
Web
Mobile
Partner Portal
PROCESS LAYER
Workflow
Orchestration
Rules Engine
Customer Service
Service
DATA
DATA DRIVEN
OPERATIONAL DATA STORE
MASTER DATA
INFRASTRUCTURE
CLOUD PLATFORM
Kubernates
Serverless
Containers

1 Introduction

1.1 The challenge of data in cities

Modern cities generate a vast amount of information, structured and unstructured, from multiple data sources and processes: IoT sensors, mobility systems, street lighting, waste management, water networks, energy platforms, social services, public safety, and even citizen interaction with the administration. This growing availability of data represents a significant opportunity to improve urban management; however, it also poses one of the greatest challenges of municipal digital transformation, namely converting scattered data into useful and manageable knowledge.

Traditionally, urban information has been fragmented into independent systems, developed vertically by each municipal department or by different technology providers. This situation has led to the emergence of information silos, hindering interoperability between departments, data availability, data reuse, and the attainment of a comprehensive view of the city.

For example, mobility data are often managed in isolation from environmental, energy, water or urban services data, preventing the analysis of critical relationships such as the impact of traffic on air quality or the effect of energy consumption on urban sustainability, or the effect of the timing and location of electric-vehicle charging and discharging on peak load in the electricity grid.

In addition to fragmentation, another fundamental challenge lies in the heterogeneity of the data. Cities manage structured, semi-structured and unstructured information, originating from legacy systems and from new digital infrastructures. This diversity demands advanced mechanisms for normalization, semantic contextualization, and quality control to ensure that the data are reliable, consistent, trustworthy and reusable.

Added to this is the need to operate in real time. Many urban decisions require immediate response capabilities: traffic incidents, extreme weather events, emergencies, public service management, and critical infrastructure monitoring. This necessitates an evolution from traditional historical analysis models to platforms capable of processing continuous information flows and supporting dynamic city management.

Real-time operation also raises the question of whether the incoming data can be trusted. Urban sensor networks degrade in predictable ways – sensor drift, packet loss and inconsistent sampling intervals – so a city platform should apply a data quality and trust framework at the ingestion layer, covering completeness, timeliness, consistency and provenance validation, before data reaches the integration or analytics tiers. Responsibility for these thresholds sits with the Data Office and, in each department, with the Data Stewards described in section 6.

However, the challenge is not solely technological. The real complexity lies in data governance. It is necessary to define who generates the information, who stores it, who verifies it, who can access it, who may share it onward and with whom, and under what conditions. Quality, traceability, security,

and privacy must be guaranteed from the design stage, especially in an environment regulated by legislation such as the General Data Protection Regulation (GDPR) and the EU Artificial Intelligence Act in the European Union, HIPAA and sectoral privacy laws in the United States, and comparable national frameworks elsewhere and by the growing public demand for transparency and ethical use of information.

Furthermore, the city is not the only data generator. Concessionary companies, transport operators, energy suppliers, universities and citizens all generate information of enormous value for urban management. Integrating these stakeholders into a secure and reliable collaborative model is another major challenge today.

In this context, data cease to be a byproduct of administrative operations and become a strategic asset for the city. Its proper management allows for the optimization of services, cost reduction, anticipation of problems, improved sustainability, and progress toward more resilient, efficient, and intelligent city models. Such an integrated model enables data innovation, resulting in new digital services and stronger municipal capabilities.

Therefore, addressing the challenge of data in cities involves moving from a fragmented and technological vision to an integrated model based on city platforms, data spaces and governance structures such as the Data Office, whose objective is to build the capability to unlock the value of data and to ensure that information becomes real public value.

1.2 Why talk about city platforms and data spaces today?

Talking about city platforms and data spaces today responds to a concrete need: to provide a strategic response to the growing complexity of contemporary urban environments. Urban data have evolved from a byproduct of municipal management to a strategic infrastructure. In a context where more than half of the world's population live in cities – and with projections of sustained growth – the efficient management of resources, mobility, sustainability, and public services depends directly on the ability to transform large volumes of data into actionable knowledge and intelligent, evidence-based decisions. This must be pursued taking into consideration the protection of individuals and their human rights.

1.2.1 The evolution of the "Smart City" towards the "Data-Driven City"

Over the past decade, the Smart City concept has been primarily associated with the vertical digitization of urban services. Examples include the installation of sensors in waste containers, traffic monitoring systems, and remote management solutions for public lighting.

While these initiatives have led to significant progress in operational efficiency, their development has been marked by considerable fragmentation. In many cases, the data generated have remained isolated in technological silos, limiting their reuse and reducing their capacity to generate added value at a systemic level.

Currently, this paradigm is being replaced by an integrated, data-driven approach. It is no longer enough to deploy sensors or digitize processes in isolation; the true value lies in the ability to interconnect information from multiple urban domains, enabling cross-sectional analysis that considers multiple layers of information. This holistic approach is based on the conceptualization of the city as (1) a complex system with all its elements in constant interaction, and (2) a constantly changing process, with a temporal evolution that allows for the observation of trends and patterns.

The theoretical approach based on land system science or urban metamorphology, applied to the use of intelligent systems data, allows traffic information to be correlated with air quality levels, and these, in turn, to feed dynamic systems for managing low-emission zones, urban planning, or sustainable mobility policies in real time.

Furthermore, this approach facilitates the transition to urban digital twin models, where the city can be simulated and analysed in virtual environments to assess the impact of different policies before their actual implementation, providing evidence-based knowledge to decision-making processes from urban design and planning to resource management.

1.2.2 The city platform as the "Operating Brain"

The City Platform is configured as the central technological infrastructure that enables the comprehensive management of the urban data lifecycle: from its collection to its advanced use. Essentially, it constitutes the operational core around which urban intelligence is built.

Its relevance in the current context is based on a series of key capabilities:

- **Real-time response capability**: It allows for continuous monitoring of the city's status and immediate response to incidents, emergencies, crisis or health and safety events, or changes in service demand. This is especially critical in areas such as security, mobility, and event management.
- **Interoperability**: It acts as an integration layer that facilitates communication between heterogeneous systems, regardless of their vendor, age, or technological standard. This is fundamental to avoiding technological dependencies and ensuring the sustainable evolution of the urban digital ecosystem. To implement this principle at the European level, the adoption of Minimum Interoperability Mechanisms (MIMs) promoted by the OASC (Open & Agile Smart Cities) network is key. The use of these MIMs (supported by standards such as FIWARE and NGSI) ensures a basic common language, avoiding vendor lock-in and allowing cities to share and scale digital solutions in an agile manner.
- **Operational efficiency and cost optimization**: Centralizing technology management reduces redundancies, eliminates duplication in the acquisition of solutions, and allows for a more efficient allocation of public resources, improving the financial sustainability of digital initiatives.

- **Scalability and flexibility**: Modern platforms are designed under modular and scalable architectures, which allows for the progressive incorporation of new use cases, data sources, and analytical capabilities without the need for structural redesigns.
- **Enabling advanced analytics**: They provide the necessary foundation for the deployment of analysis methodologies based on data science, location intelligence, business intelligence, artificial intelligence, machine learning, and predictive analytics, allowing evolution towards proactive management models.

1.2.3 Data spaces: the leap towards the federated collaborative ecosystem

In line with the conceptualization of urban space as a complex system of multiple actors, data spaces represent the capacity of these actors to exchange information. If the City Platform can be understood as the "internal brain" of the administration, data spaces represent the exchange ecosystem that connects the city with external actors, both public and private.

Data spaces are configured as federated environments that allow information sharing under principles of sovereignty, security and trust, aligning with European strategies for creating a single data market.

Its relevance lies in several fundamental aspects:

- **Sovereignty and Trust**: Unlike traditional information-sharing models, data spaces allow owners to maintain control over their data, defining who can access it, under what conditions, for what purpose, under what legal basis, and for how long, and ensuring that privacy-enhancing technologies (PETs) are used to safeguard the data. This approach strengthens trust among the various actors in the ecosystem.
- **Public-private collaboration**: Cities are not the only data generators. Telecommunications companies, transport operators, energy companies, and citizens themselves generate information critical to urban management. Data spaces provide a secure and regulated environment where these actors can collaborate to create shared value. Participation is subject to safeguards designed to protect the individuals to whom the data relates.
- **Boosting the data economy**: Enabling controlled access to combined datasets fosters the creation of new digital services, innovative applications, and data-driven business models. This contributes to the development of a more dynamic and competitive economic fabric.

1.2.4 The strategic role of the data office

Technology alone does not guarantee value creation. Large volumes of data are useless without a suitable governance model. In this context, the Data Office emerges as a key element for structuring, coordinating, and leading the city's data strategy.

Its main functions include:

- **Quality guaranteed**: Ensure the reliability, consistency, integrity and updating of information, establishing metrics, validation processes and continuous improvement mechanisms.
- **Ethics and privacy**: In a context of growing concern about surveillance, the Data Office acts as a guarantor that the use of information complies with the GDPR and ethical principles, protecting the anonymity of the citizen.
- **Organizational and cultural transformation**: Break down resistance to change within the administration by encouraging departments to share information instead of guarding it as their own private property. This is supported by structured change-management practices rather than by training alone. It also requires building trust with external stakeholders – private operators, utilities and universities – whose willingness to participate in a federated ecosystem depends on confidence in the rules, not on internal culture.
- **Governance and strategic alignment**: It defines policies, standards, and management models that ensure data use is aligned with the city's strategic objectives.
- **Training and talent**: It promotes the development of internal capabilities in data management and analysis, a key element for the sustainability of the model.

1.2.5 The current context: why now?

The adoption of city platforms and data spaces responds to the convergence of a series of factors that make this moment especially relevant:

1) **Ecological transition and climate demand**: The fight against climate change requires extreme precision in measuring carbon footprints and managing resources (water, energy). Without integrated platforms, achieving climate neutrality goals is impossible.
2) **Technological maturity**: Data platforms and spaces provide the massive, structured datasets that can be used in multiple analytical methodologies to make observations and predictions about urban dynamics such as machine learning algorithms.
3) **Boosting European regulatory frameworks**: The European Union's Data Strategy and legislation such as the Data Act are driving the creation of shared data spaces. Cities that fail to adopt these models will fall behind in attracting funding and in their ability to innovate.
4) **Growing citizen demand**: Citizens demand more efficient, personalized and transparent public services, as well as greater accountability from government agencies.

In short, talking about city platforms and data spaces today is essentially talking about resilience, competitiveness, and urban sustainability. It means recognizing that the city of the future is not built solely on physical infrastructure, but on an architecture of shared, secure, and ethically governed data.

The effective integration of these capabilities, under the leadership of a Data Office, allows cities to evolve from merely digitized models to truly smart urban ecosystems. These ecosystems are capable not only of responding to current challenges but also of anticipating them, tangibly improving citizens' quality of life and strengthening cities' strategic positioning in the data economy.

2 What is a city platform and a data space?

2.1 City platform definition and architecture

A city platform is conceived as the central enabling element of smart city services, responsible for integrating, managing, and utilizing information from multiple urban sources in a consistent manner. Its main objective is to improve the operational efficiency of municipal administration, optimize the delivery of public services, and facilitate data-driven decision-making.

The platform acts as a horizontal, interoperable and reusable system, supporting the different functional areas of the city (mobility, environment, energy, security, urban services, governance, among others), avoiding isolated solutions and favouring a unified, evolutionary and sustainable approach over time.

The design and deployment of the city platform is based on a series of fundamental principles:

- **Interoperability**: The ability to integrate with heterogeneous systems, existing and future, through the use of open standards, well-defined interfaces, and information exchange mechanisms. To implement this principle at the European level, the adoption of the Minimum Interoperability Mechanisms (MIMs) promoted by the OASC (Open & Agile Smart Cities) network is key. The use of these MIMs (supported by standards such as FIWARE and NGSI) ensures a basic common language, avoiding technological dependence on third parties (vendor lock-in) and allowing cities to share and scale digital solutions in an agile manner. The emphasis on open standards like FIWARE and NGSI is particularly critical for cities in developing countries. Adopting proprietary, closed-source platforms can lead to a severe vendor lock-in, creating long-term technological and financial dependencies that public budgets cannot sustain. For these cities, a commitment to open-source components and open standards is not just a technical choice; it is a strategic guarantee of digital sovereignty, long-term sustainability, and affordability.
- **Technological neutrality and modularity**: independence from specific manufacturers and technologies, allowing the progressive evolution of the different components without affecting the whole.
- **Scalability and flexibility**: adaptation to the growth in data volume, number of services and users, while maintaining system performance and stability.

- **Reuse of information and services**: provision of common capabilities and horizontal services reusable by multiple use cases and city areas.
- **Security and privacy by default and design**: comprehensive information protection, privacy-enhancing technologies (PETs) access controls and regulatory compliance throughout the entire data lifecycle.
- **Data governance**: clear definition of responsibilities, quality, traceability and use of urban information.

There are different ways to approach the architecture of a city platform. One of the most widely accepted is that proposed by the UNE 178104 standard (and derived Recommendations ITU-T Y.4200 and ITU-T Y.4201), based on a layered logical architecture, facilitating the separation of responsibilities, interoperability, and independent evolution of each component. These layers are:

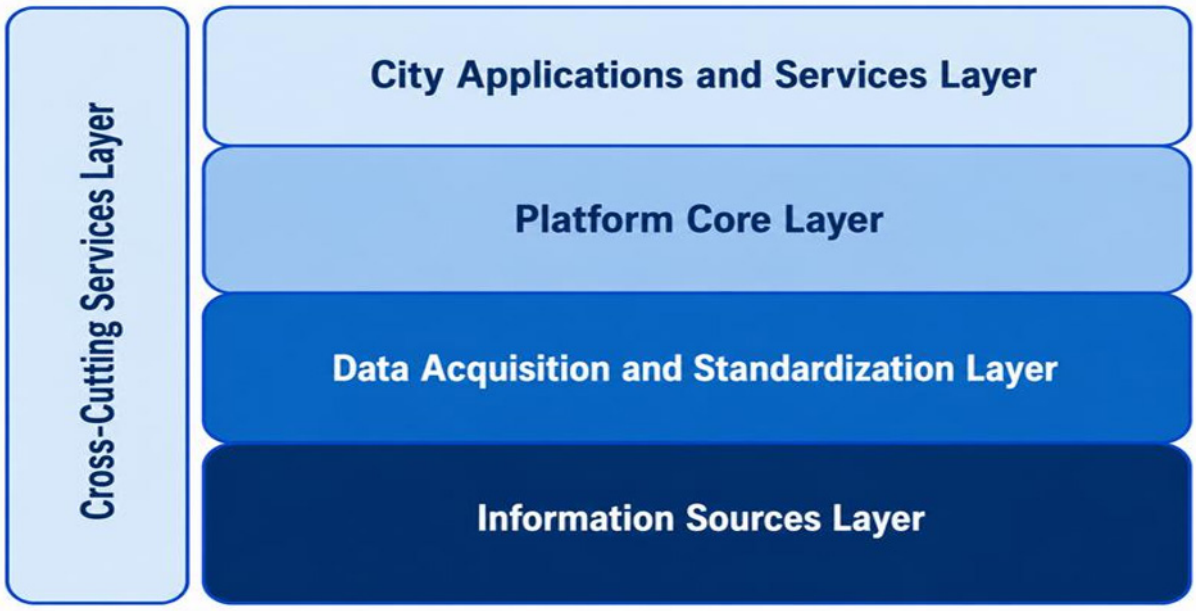
- **Information sources layer**: This layer includes all city data sources such as sensors and IoT devices, control systems, sector-specific applications, municipal corporate systems, and external sources. It is responsible for generating and capturing urban information.
- **Data acquisition and normalization layer**: Responsible for ingesting data from various sources, providing connectivity mechanisms, protocol adaptation, validation, normalization, and contextualization of information according to common data models. In the national and European context, this standardization relies heavily on de facto standards such as the FIWARE ecosystem and the NGSI context management standard. Its adoption at this layer is strategic, as it provides a common format for representing the city's state in real time, ensuring semantic interoperability from the ground up and laying the technological foundation for the future creation of urban/local digital twins.
- **Platform core layer**: This constitutes the functional core of the platform, providing horizontal capabilities such as:
    - Storage and management of historical and real-time data.
    - Processing, analysis and exploitation of information.
    - Management of events, alarms and urban assets.
    - Catalogue of data and metadata.
    - Exhibition of services and APIs for internal and external consumption.

    This layer allows the systems that produce information to be decoupled from the systems that consume it.
- **Cross-functional services layer**: It includes cross-cutting functionalities common to all applications such as:
    - Security, identity management, and access control.

- Platform monitoring and operation.
- User, role, and permission management.
- Orchestration of processes and workflows.
- Data governance and information quality control.

- **City applications and services layer**: It consists of the final services and applications, internal and external, that consume the information and capabilities of the platform to offer value to the different actors: municipal managers, operators, policymakers, citizens and companies.

Figure 1: City platform layered architecture



Source: Author

The city platform incorporates an interoperability and openness approach, aimed at facilitating the creation of collaborative digital ecosystems, promoting:

- Controlled exposure of data and services to third parties allowed to access to the platform under certain restrictions.
- Integration with other institutional or territorial platforms.
- The reuse of urban information and the development of new value-added services.

In this context, the city platform should be understood as a strategic digital infrastructure, oriented towards data and services, which acts as a common base for the progressive development of a more efficient, interoperable, sustainable city focused on the needs of its citizens.

2.2 Definition and architecture of a data space

2.2.1 Advanced conceptual definition

A Data Space (DS) is a logical, decentralized, and federated infrastructure designed to enable the sovereign, reliable, and secure exchange of data assets among multiple heterogeneous participants. Breaking with the paradigm of centralized repositories (data lakes or data warehouses), a DS does not store data centrally; instead, it provides the technical and legal control plane that allows data to remain at its source (at the edge, on-premises, or in private clouds) while making it accessible and actionable under strict, automated rules.

The fundamental and differentiating principle of a data system is data sovereignty. This means that the data owner maintains absolute decision-making authority over the lifecycle of their asset, specifying who can access it, when, for what purpose, and under what technical or economic conditions.

2.2.2 Detailed reference architecture

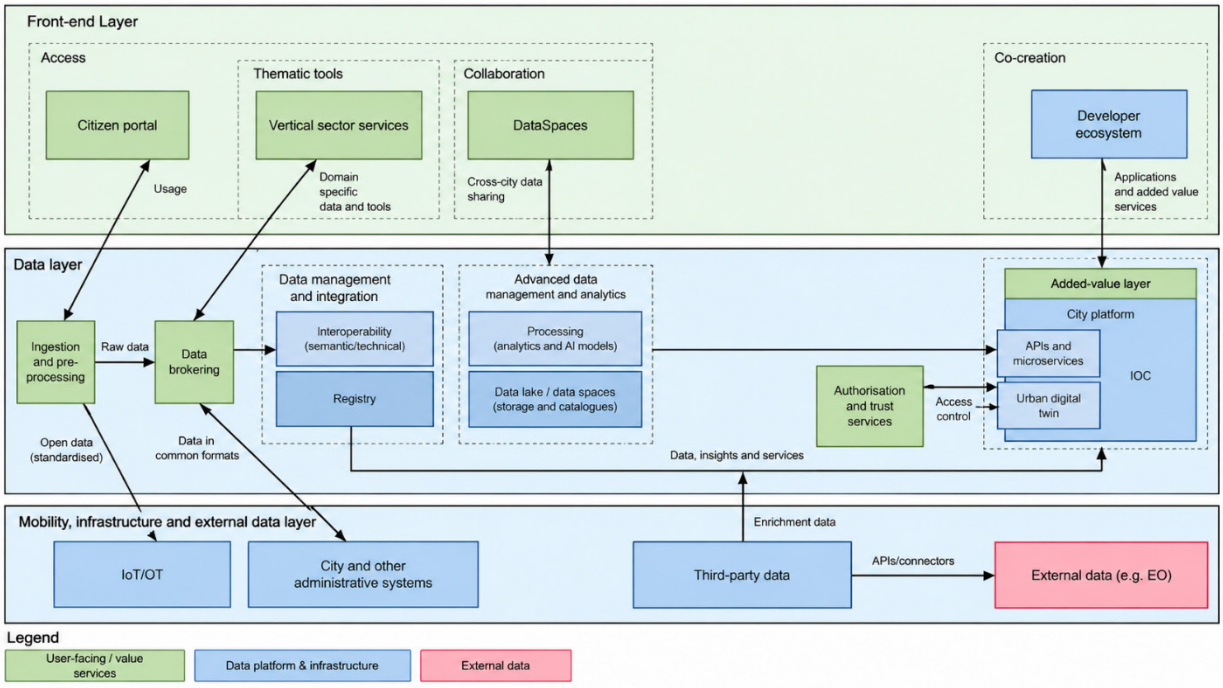
Modern data space architecture is based on global reference models such as those proposed by the International Data Spaces Association (IDSA) and Gaia-X. This architecture is structured into operational planes (plans) and functional layers that ensure technical and semantic interoperability.

For reference, an architecture diagram of a real-world data space implementation is included, following the IDSA and Gaia-X proposals, divided into three layers:

- **Presentation layer**: Serves as the entry point for businesses to the data space. Through the Portal, organizations can register and join the ecosystem (onboarding), request and manage connectors as a service (Connector-SaaS), and explore available data offerings through the Catalogue. The connector also allows businesses to publish and manage their own data offerings independently.
- **Dataspace layer**: The operational core of the architecture. It manages data flows between participants, including the negotiation of data contracts, the definition and application of usage policies, and secure transfers between organizations. The service orchestrator manages the automated deployment of connectors, while the Marketplace centralizes data offerings, and the audit service records all interactions to ensure traceability. The EDC (Eclipse Dataspace Connector) acts as the central component for the negotiation and execution of exchange agreements.
- **Identity and trust layer**: Provides verification mechanisms that ensure that all participating entities – organizations, individuals, connected devices and autonomous software agents – are legitimate and comply with ecosystem requirements. Each entity type raises a distinct accountability question, and the layer must, therefore, support digital identity and credential management, authorization management, authentication and access control for all of them.

Through integration with the FNMT (Spanish National Mint), Gaia-X Digital Clearing House, and the IAM Dataspace – federated with Microsoft Entra ID – authentication, regulatory compliance verification, and verifiable credential management are ensured throughout the entire lifecycle of interactions between organizations. Architecturally, this is a zero-trust model: no participant is trusted by virtue of its network position, and every request is authenticated and authorized against the applicable usage policy. Supporting security controls should be aligned with ISO/IEC 27001 and equivalent national schemes.

Figure 2: Reference architecture of a data space implementation



Source: Author

The Data Plane and the IDS Connector

The IDS Connector (International Data Spaces Connector) is the core technological component. It acts as the sovereign gateway for each participant. Its function is not only to transfer bits, but also to ensure policy compliance (Policy Enforcement Point - PEP).

Connector technical specifications

- **Data encapsulation**: The data are not sent "raw". They are encapsulated in a logical container that includes the metadata and the attached usage policy.
- **Containerization**: The connector is usually implemented using containerization technologies (Docker, Kubernetes) to isolate data processes and ensure the security of the execution environment (Trusted Execution Environment if necessary).

- **Transfer protocols**: Supports industry-standard protocols such as HTTPS (TLS 1.3), MQTT for IoT, and specialized protocols such as OPC UA for industrial environments, ensuring end-to-end encryption.
- Currently, the leading open-source implementation for deploying these components is the Eclipse EDC (Eclipse Dataspace Components) framework. Widely adopted by major European initiatives (such as Gaia-X and Catena-X), Eclipse EDC provides a proven, modular technology foundation for building sovereign connectors. Its use ensures that organizations can connect to dataspaces using a market standard that natively integrates secure transfer (data plane) with contract negotiation and ODRL policy validation (control plane).

The Governance and Trust Plane (Control Plane)

This plane manages the network logic and validates the identity and conformity of the nodes.

- **Federated Identity Services (IdP/DAPS)**: It uses standards such as OIDC (OpenID Connect) or Verifiable Credentials (VC) based on W3C DID (Decentralized Identifiers). The Dynamic Attribute Provisioning Service (DAPS) issues dynamic security tokens that validate a connector's attributes (e.g., "this connector is certified," "this participant is a European SME") before each transaction.
- **Dynamic Trust Mechanism**: Before Connector A sends data to Connector B, there is a technical "handshake" where both validate their credentials to DAPS and verify that their technical certifications have not been revoked.

The Semantic Interoperability Layer

To ensure that the receiver "understands" the sender's data in an automated way, rigorous semantics are required.

- **Federated Metadata Catalogue**: A component of Broker indexes the metadata of available datasets. Participants publish DCAT-AP (Data Catalogue Vocabulary - Application Profile) descriptions that describe what data they have, but not the data itself.
- **Information models and ontologies**: Shared ontologies (e.g., sectoral semantics for automotive, health, or energy, or cross-cutting models such as VDI 3637) are used to normalize the meaning of attributes, allowing automatic data transformation (Data Mapping) between different proprietary formats.

2.2.3 The sovereignty mechanism: control of use and digital contracts

The crucial difference between Access Control and Usage Control is that the former decides "who enters" and the latter decides "what can be done inside".

Formalization with ODRL

Usage control is formalized through digital contracts expressed in policy languages such as ODRL (Open Digital Rights Language), standardized by the W3C. An ODRL contract in a digital domain is machine-readable and defines:

- **Permissions**: (e.g., allow reading).
- **Prohibitions**: (e.g., prohibit copying or resale).
- **Duties (Obligations)**: (e.g., anonymize before processing, delete after 10 days).
- **Constraints**: (e.g., only accessible from IPs within the European Union).

Enforcement mechanism: When a consumer requests data, the sending connector evaluates the ODRL policy. If the conditions are met, it encapsulates the data and attaches the policy. The receiving connector is obligated by its certification to execute this policy locally.

2.2.4 Key Technical components and artifacts

Table 1: Key technical components and artifacts of a data space

Technical Component	Role in architecture	Technical description and functions
IDS connector	Policy Enforcement Point (PEP)	Containerized gateway that manages secure transfer and execution of ODRL usage policies.
Metadata broker	Resource Discovery & Indexing	Service that collects and maintains a federated index of metadata (DCAT-AP) for search and discovery.
Identity provider (IdP)/DAPS	Dynamic Trust Authority	Manages identities (DID/VC) and issues dynamic attribute tokens for real-time node validation.
Clearing house	Transaction Logging & Audit	Immutable ledger (sometimes based on DLT/Blockchain) for auditing transfers and resolving legal disputes.
Vocabulary hub	Semantic Registry	Server that hosts shared ontologies and vocabularies to ensure semantic interoperability.
Data app store	Algorithm Marketplace	Repository of certified microservices for data processing (e.g., cleaning, AI) "inside" the connector.

2.2.5 Cutting-edge technical challenges

The implementation of functional Data Spaces is at the technological frontier:

1) **Inter-sectoral semantic alignment**: Making health data models interoperable with insurance or drug research models in an automated way remains a highly complex challenge (Ontology Matching).

2) **Computing sovereignty (compute-to-data)**: The challenge of moving the algorithm to the data (instead of the data to the algorithm) in federated environments, ensuring that the algorithm owner cannot "steal" the data while processing it.

3) **Scalability of the trust framework**: Efficient, real-time management of certificate revocations and dynamic attribute validation for thousands of concurrent nodes.

4) **Inter-space interoperability (data space Interoperability)**: Define standard protocols so that a connector from a sectoral DS (e.g., Catena-X) can natively transact with a connector from another DS (e.g., a national transport DS).

2.2.6 Difference with traditional models

- **Data warehouse/lake**: The data are moved to a central platform. Control usually passes to the platform owner.
- **Data space**: The data stays at the source. Control remains with the data creator through smart connectors. The principle that data stays at the source concerns where control sits, not where computation happens. Hybrid patterns – a curated analytical store for historical series, cross-domain joins or machine-learning readiness – remain compatible with this model, provided the source remains authoritative and the sovereignty and usage-control rules travel with the data wherever it is copied.

2.3 Differences with traditional data platforms

Although a city platform shares certain technological components with traditional data platforms (such as data warehouses, data lakes, or enterprise analytics platforms), its scope, purpose, and functional requirements present substantial differences that require a specific approach.

First, regarding functional approach and purpose, traditional data platforms are generally geared towards the internal analytical exploitation of corporate information, with a primary focus on reporting, business intelligence, and historical analysis. In contrast, the city platform aims to enable the operation, management, and evolution of urban services, combining analytical exploitation with near real-time operational capabilities.

The city platform is not limited to data analysis, but acts as a digital infrastructure enabling services, supporting operational processes, decision-making, automation, and collaboration among multiple actors.

Regarding the nature and heterogeneity of the data, in a traditional data platform, the sources are usually homogeneous corporate systems, with relatively stabilized data models and defined update cycles.

In contrast, the city platform manages a wide variety of data sources and types, including:

- Real-time data from sensors and IoT systems.
- Information from industry platforms and legacy systems.
- Structured, semi-structured and unstructured data.
- External and contextual information (e.g., weather, traffic, events).

This heterogeneity necessitates the incorporation of advanced data normalization, contextualization, and semantic management capabilities that go beyond traditional approaches.

Regarding real-time and event management, conventional data platforms are typically geared towards batch processes or those with high latency, suitable for historical analysis and report generation. The city platform, on the other hand, must support real-time or near-real-time processes, including:

- Event and alarm management.
- Continuous monitoring of urban assets and services.
- Immediate reaction to incidents or critical situations.

This introduces specific requirements in terms of architecture, data flow processing and scalability.

Furthermore, regarding service orientation and interoperability, while a traditional data platform is usually conceived as a centralized repository for internal consumption, the city platform is designed from the outset for the exposure of data and capabilities through reusable services.

The city platform natively incorporates:

- APIs and interoperability mechanisms.
- Integration with external applications and third-party systems.
- Support for open ecosystems and inter-institutional collaboration.

Data are not an end in themselves, but a shared asset that enables cross-cutting services and use cases.

Regarding data governance and multiple stakeholders, in traditional environments, data governance is typically centralized within a single organization, with well-defined roles and responsibilities. At the city level, the platform must support a more complex data governance model, involving multiple municipal departments, concessionary companies, public bodies, and potentially, private third parties and citizens. This requires advanced mechanisms for:

- Access control and permissions.

- Data usage traceability.
- Management of responsibilities and quality of information.

Finally, regarding evolution and sustainability, traditional platforms tend to evolve incrementally within a relatively stable corporate framework. A city platform, however, must be designed for continuous evolution, capable of incorporating new services, technologies, and data sources over time, avoiding rigid dependencies and promoting technological and economic sustainability.

In summary, although they share technological foundations, the city platform differs significantly from traditional data platforms due to its focus on urban operations, its cross-cutting approach, its real-time management capabilities, and its role as an enabler of digital services and ecosystems. These differences necessitate addressing its definition and architecture from a perspective tailored to city-specific requirements, adapted to the complexity and uniqueness of the urban environment.

The following table summarizes the key differences between traditional data platforms and city platforms.

Table 2: Traditional platforms and city platforms differences

Dimension	Traditional data platform	City platform
Primary purpose	Supports internal analytics, reporting, business intelligence, and historical analysis.	Supports the operation, management, optimization, and evolution of urban services. Combines analytics with operational capabilities.
Business focus	Enterprise-centric, serving the needs of a single organization.	City-centric, serving multiple urban domains and stakeholders across the urban ecosystem.
Role of the platform	Primarily a repository and processing environment for data analysis.	A digital infrastructure that enables services, operations, automation, decision-making, and collaboration.
Data sources	Mainly internal corporate systems with relatively standardized structures.	Diverse sources including IoT devices, sensors, legacy systems, operational platforms, external data providers, and contextual data sources.
Data types	Predominantly structured data.	Structured, semi-structured, and unstructured data, including streaming and event-based information.
Data heterogeneity	Limited and relatively stable.	Very high, requiring normalization, contextualization, and semantic interoperability mechanisms.
Update patterns	Periodic updates and batch-oriented ingestion.	Continuous ingestion with real-time or near-real-time data flows.
Processing model	Historical and retrospective analysis.	Operational and analytical processing simultaneously.
Real-time capabilities	Usually not critical; latency is often acceptable.	Essential for monitoring, event processing, alarm handling, and incident response.

Dimension	Traditional data platform	City platform
Event management	Generally outside the platform scope or managed separately.	Native capability for event detection, alerting, and operational response.
Asset monitoring	Limited focus on physical assets.	Continuous monitoring of urban assets, infrastructure, and public services.
Interoperability	Typically focused on internal systems integration.	Designed from the outset for interoperability across organizations, domains, and platforms.
API exposure	Often optional or limited.	Core design principle, exposing data and capabilities through reusable services and APIs.
Ecosystem orientation	Closed or organization-centric environment.	Open ecosystem supporting external applications, third parties, and institutional collaboration.
Data consumption model	Internal consumers are the primary users.	Multiple internal and external consumers, including departments, operators, businesses, and citizens.
Governance model	Centralized governance within a single organization.	Federated governance involving multiple public and private stakeholders.
Stakeholder complexity	Limited number of actors with clearly defined responsibilities.	Multiple municipal departments, utilities, public agencies, concessionaires, private partners, and citizens.
Access control requirements	Organizational access management.	Multi-organizational access control, data-sharing policies, and cross-domain permissions.
Traceability and accountability	Focused on internal compliance and auditing.	Requires advanced traceability, accountability, and information ownership management across stakeholders.
Scalability drivers	Data volume and analytical workload growth.	Data volume, real-time events, connected devices, services, and ecosystem expansion.
Evolution model	Incremental evolution within a relatively stable business environment.	Continuous evolution with ongoing integration of new technologies, services, and urban use cases.
Technology strategy	Often optimized for enterprise efficiency.	Designed to avoid vendor lock-in and ensure long-term technological and economic sustainability.
Success criteria	Improved business insights and operational reporting.	Improved urban operations, service delivery, resilience, interoperability, and citizen outcomes.

2.4 City ontology

The city ontology is a key structural element of the city platform, providing a common conceptual model that allows for the coherent representation, interpretation, and correlation of urban information from multiple sources and functional domains. Its purpose is to establish a shared language that facilitates semantic interoperability between systems, applications, and services, ensuring that data has a homogeneous, understandable, and reusable meaning throughout the urban ecosystem.

Therefore, the city ontology defines an organized set of entities, attributes, and relationships that describe the main elements of the urban environment such as assets, services, events, locations, organizations, and people, as well as the interactions between them.

This conceptual model transcends the specific data models of each system, providing a common semantic layer that allows the integration of heterogeneous information without losing context or meaning, regardless of its origin or format.

Within the city platform, ontology plays a fundamental role as an element of coherence and integration, enabling:

- The semantic normalization of data from different sources.
- The correlation of information between different areas of the city.
- Data reuse for multiple use cases and services.
- Reducing ambiguities and duplications in the interpretation of information.

Thus, the ontology acts as a common reference for both the processes of data ingestion and storage and for the services of exploitation, analysis and visualization.

Furthermore, the city ontology directly enables semantic interoperability, complementing technical integration mechanisms. While interfaces and APIs facilitate data exchange, the ontology ensures that this data are interpreted in the same way by all systems that consume it.

Thanks to the ontology, the platform can:

- Integrate heterogeneous systems without the need for specific point-to-point transformations.
- Facilitate the exposure of data and services to third parties with a clear and consistent meaning.
- Promote the development of cross-cutting applications that combine information from multiple areas of the city.

Regarding the evolution of ontology, the ontology of the city requires a specific governance model that guarantees its coherence, quality, and alignment with the city's real needs. This governance must consider:

- The definition of those responsible for maintenance and evolution.
- Controlled management of changes and expansions.
- Alignment with external models and standards when necessary.
- Documentation and dissemination of the model to facilitate its adoption.

A well-governed ontology becomes a strategic asset, capable of evolving in an orderly manner without compromising the stability of existing services.

In short, the city ontology provides the semantic foundation that allows heterogeneous data to be transformed into understandable and reusable information, becoming an essential element for ensuring the interoperability, reusability, and scalability of the city platform. Its correct definition and management are key to maximizing the value of urban information and facilitating the development of innovative and cross-cutting services.

The ontology of a city is usually structured in functional domains, which group concepts related to different areas of urban management such as mobility, environment, energy, infrastructure, urban services or security.

Each domain defines:

- Main entities (e.g., assets, sensors, events, or resources).
- Relevant attributes that describe these entities.
- Relationships between entities, both within the same domain and with other domains.

This modular approach allows for a progressive evolution of the ontology, incorporating new domains or expanding existing ones as the platform and city services grow.

We can consider the following use cases, each associated with several domains, each covered by an ontology. These should not be considered separate domains, as one ontology can reference elements of another, thus ensuring that the city's semantic information is properly interconnected and related.

- Smart mobility use case
    - Parking ontology (https://github.com/EDINT-Ontologia/edint-ontologia-aparcamiento): An ontology designed to represent data associated with public and private parking facilities in a municipality, both on and off public roads. It allows for modelling aspects such as parking typology, location, capacity, occupancy, access, types of spaces, and restrictions based on vehicle type or permit, providing support for mobility management and urban services related to parking.
    - Vehicle census ontology (https://github.com/EDINT-Ontologia/edint-ontologia-censovehiculars): An ontology designed to represent the vehicle census or registry managed by a local entity, containing information relevant to tax and mobility management. It includes data on registered vehicles, their type, characteristics, and relationship to urban permits, facilitating its use in contexts such as parking regulations, access to restricted areas, or mobility policy planning.
    - Infrastructure ontology (https://github.com/EDINT-Ontologia/edint-ontologia-infraestructura): An ontology that describes municipal public infrastructure, including educational, cultural, social, and sports facilities, parking, and shared mobility stations, among others. It allows for the representation of these assets, their location, characteristics,

and relationships with consumption, maintenance, and associated uses, serving as a basis for integrating information related to urban mobility and the services associated with these assets.

- Regulatory zone ontology (https://github.com/EDINT-Ontologia/edint-ontologia-zonaregulatoria): This ontology is designed to represent defined regulatory zones in urban areas such as low-emission zones, loading and unloading areas, or zones with access and traffic restrictions. It allows for the modelling of functional zones superimposed on the administrative structure, their spatial boundaries, and the rules that govern them, facilitating the management and control of mobility in regulated environments.

- Use case of managed cities and territories

  - Air quality ontology (https://github.com/EDINT-Ontologia/edint-ontologia-calidad-aire): A specialized ontology for representing air quality monitoring stations, sensors, and observations. It models pollutants, environmental variables, and measurement results, relying on a common structure of sensors and observations, which allows for the monitoring and analysis of air pollution in urban environments.
  - Climate management ontology (https://github.com/EDINT-Ontologia/edint-ontologia-climatologia): An ontology designed to represent climatological variables and observations in urban areas such as temperature, humidity, wind, and precipitation. It allows for the description of weather stations, sensors, and associated data, providing support for climate monitoring and the management of atmospheric phenomena relevant to territorial and urban planning.
  - Ontology of noise pollution (https://github.com/EDINT-Ontologia/edint-ontologia-contaminacion-acustica): An ontology that extends the environmental sensor model to represent urban noise observations. It allows for the description of acoustic sensors, locations, measurements, and specific characteristics of noise pollution, facilitating the assessment of noise impact and compliance with the limits established in current regulations.
  - Photovoltaic management ontology (https://github.com/EDINT-Ontologia/edint-ontologia-fotovoltaica): Ontology designed to represent photovoltaic installations integrated into municipal infrastructure. It models solar generation elements, as well as the measurement of energy production, consumption, storage, and feed-in, serving as a basis for energy management and the promotion of sustainability policies.
  - Environmental ontology (https://github.com/EDINT-Ontologia/edint-ontologia-medio-ambiente): A general ontology for representing urban environmental sensors and their observations, encompassing domains such as climate, air quality, and noise. It provides a common and reusable structure for describing stations, sensors, and measurements, facilitating the coherent integration of different environmental domains.
  - Supply ontology (https://github.com/EDINT-Ontologia/edint-ontologia-suministro) An ontology designed to represent the supply services associated with municipal infrastructure assets such as electricity, water, or gas, as well as the measurement of their consumption

and production. It allows for the modelling of energy and resource flows, supporting the efficient and sustainable management of urban utilities.

- Economic activity map use case
  - Cadastre ontology (https://github.com/EDINT-Ontologia/edint-ontologia-catastro): An ontology designed to represent cadastral information, including parcels, buildings, and properties, as well as their physical characteristics and spatial relationships. It provides a semantic basis for integrating relevant territorial and heritage data into the analysis of economic activity.
  - Ontology of premises census (https://github.com/EDINT-Ontologia/edint-ontologia-censo-locales): An ontology designed to describe premises and establishments located within the municipality, allowing for the representation of their location, type, and status. It facilitates the analysis and management of the territory's commercial and productive fabric.
  - Real estate supply ontology (https://github.com/EDINT-Ontologia/edint-ontologia-oferta-inmobiliaria): An ontology that models the available real estate supply in urban areas, including properties for sale or rent, their basic characteristics, and their relationship with the urban environment. It allows for the integration of real estate information into economic and territorial analyses.
  - Commercial promotion ontology (https://github.com/EDINT-Ontologia/edint-ontologia-promocion-comercial): An ontology designed to represent initiatives, campaigns, and commercial promotion actions developed in the municipality. It allows for the description of activities, areas of application, and relationships with zones, sectors, or economic actors, supporting the revitalization of local commerce.
  - Tourism ontology (https://github.com/EDINT-Ontologia/edint-ontologia-turismo): An ontology designed to represent the municipality's tourism resources, services, and infrastructure such as points of interest, accommodations, events, and routes. It facilitates the integration of tourism information into the analysis of economic activity and the development of services for visitors and residents.

2.5 Key principles: trust, interoperability, and governance

The city platform must be based on a series of key principles that guarantee its viability, sustainability, and acceptance by all stakeholders. Among these, trust, interoperability and governance stand out across all areas, understood not as isolated elements, but as interrelated pillars that shape the platform's design, operation, and evolution.

- **Trust as a fundamental element**: Trust is an essential requirement for the success of any city platform, as it determines the effective adoption by municipal services, operators, collaborating entities and, ultimately, the citizens. Trust is built based on transparency, inspection, and adaptation.

- **Transparency** creates visibility.
- **Inspection** is achieved when the team and stakeholders regularly inspect progress, outcomes, risks, and the platform state and it is important to create shared understanding.
- **Adaptation** comes when inspection shows that something is wrong or no longer useful and the team adjusts the plan, process, or platform, thus creating confidence that the team can respond.

More in detail, the platform must build trust through:

- **Information protection** throughout its entire life cycle, guaranteeing the confidentiality, integrity and availability of the data.
- **Transparency in data processing** facilitating traceability, access control, and knowledge of who uses the information and for what purpose of use.
- **Operational reliability** ensuring the continuity of services and the quality of the information provided.
- **Regulatory compliance** especially in matters of personal data protection, information security and responsible use of technology.

Incorporating security and privacy from the design stage not only reduces risks, but also reinforces the perception of the platform as a trustworthy and secure environment for information exchange and service delivery.

- **Interoperability as an enabler of the urban ecosystem**. Interoperability is a structural principle that allows the city platform to act as an integrating axis of the urban digital ecosystem. Its objective is to facilitate communication and information exchange between heterogeneous systems, avoiding technological dependencies and information silos.

  This principle is embodied in:

  - The use of open standards and common data models that facilitate the integration of new sources and services.
  - The exposure of well-defined interfaces and APIs, which allow the controlled consumption of data and capabilities by internal and external applications.
  - The ability to integrate with both legacy systems and emerging technologies, preserving existing investments.
  - Compatibility with platforms at other institutional or territorial levels, promoting inter-administrative collaboration.

  Interoperability transforms the platform into an enabler of innovation, allowing the reuse of data and services and fostering the development of new use cases in an agile and sustainable way.

- **Data and platform governance**. Governance is the framework that allows for the organization, coordination, and regulation of the city platform's operation and the use of the information it manages. In an urban environment, where multiple actors and responsibilities converge, governance takes on a particularly important role.

  Governance should encompass, among other aspects:

  - **Definition of roles and responsibilities** on the generation, management, custody and use of data.
  - **Data quality policies** ensuring consistency, updating and reliability of the information.
  - **Access and usage rules** adapted to different user profiles and levels of information sensitivity.
  - **Monitoring and control mechanisms**, which allow for the evaluation of the platform's performance and its alignment with the city's strategic objectives.

  Effective governance is not only technological, but also organizational and strategic, and must evolve in a coordinated manner with the platform itself and with the needs of the city.

Trust, interoperability, and governance form an inseparable whole that determines the true value of a city platform. Interoperability without governance can generate risks and loss of control; governance without interoperability limits reuse and innovation; and without trust, neither principle can be sustained over time.

Therefore, these principles must be integrated across the board into the definition of the architecture, operational processes and organizational model of the platform.

In conclusion, the proper incorporation of the principles of trust, interoperability, and governance allows the city platform to consolidate itself as a legitimate, secure, and sustainable digital infrastructure, capable of supporting the complexity of the urban environment and evolving as a key piece in the digital transformation of the city.

3 What is the purpose of a data space in a city?

3.1 Benefits for urban management and the generation of public value

An Urban Data Space is a decentralized and secure ecosystem that allows different stakeholders (public administrations, private companies, research centres, and citizens) to share, access, and utilize data securely, interoperable, and under principles of sovereignty, trust, and control. Its ultimate goal is to maximize the value of data as a strategic asset to support public decision-making and generate economic and social benefits. Unlike traditional platforms, which are typically closed "read-and-write" systems, the data space acts as a knowledge marketplace where data sovereignty

is guaranteed: the owner of the information decides who can access it, for what purpose, and under what conditions.

The implementation of data spaces in urban areas responds to the need to evolve towards more efficient, collaborative, and evidence-based management models. In a context characterized by the increasing complexity of cities, the multiplicity of actors, and the massive generation of information, data spaces are positioned as a key instrument for establishing advanced data governance.

The following section describes in detail the fundamental benefits that a data space brings to the management of modern cities. Worked examples from cities that have already implemented comparable approaches are collected separately.

Two conditions determine whether these benefits materialize. The first is a data governance framework that is in place before integration begins, since silos are dismantled by agreed rules rather than by technology. The second is an incentive structure for non-municipal data holders: private operators will not contribute data because a framework invites them to, but because participation returns something of value – access to complementary datasets, regulatory certainty, or a commercial position in the ecosystem. Section 4.3.1 sets out the participation framework this requires.

3.1.1 Breaking down silos and cross-cutting vision

The main benefit for an urban manager is the ability to connect areas that have historically operated in isolation.

- **Integrated management**: A data space allows the urban planning department to cross-reference information with the environment and transportation departments. For example, it can analyse how the creation of a new pedestrian zone affects not only traffic, but also noise levels and commercial activity in the area in real time.
- **Interoperability**: It eliminates technical barriers. It doesn't matter if the bus data comes from a private company and the streetlight data from a public contractor; in the data space, everyone "speaks" the same language, facilitating a 360-degree view of the city.

3.1.2 Optimization of operational efficiency and cost savings

Data-driven management allows a shift from a "reactive" maintenance model (repairing when it breaks) to a "predictive" one (acting to prevent situations with negative impact).

- **Critical resource management**: It allows for the optimization of water and energy consumption in public buildings by identifying waste patterns.

- **Smart service routes**: Waste collection or street cleaning services can adapt their routes based on actual demand detected by sensors or citizen reports, reducing fuel consumption and CO_2 emissions.

3.1.3 Improvement in strategic decision making

A data space transforms political intuition into scientific evidence.

- **Scenario simulation**: Before implementing a drastic measure such as changing the direction of a main artery, managers can use shared space data to perform impact simulations (digital twins) and anticipate unintended consequences.
- **Long-term urban planning**: It allows projecting the growth of the city (need for schools, health centres or transport) based on demographic and mobility trends cross-referenced with economic activity data.

3.1.4 Promotion of public-private collaboration

The city does not possess all the necessary data to be efficient; much of the relevant information is in private hands (telephone operators, shared mobility platforms, electricity networks).

- **Secure exchange**: The data space provides a framework of trust for private companies to share aggregated and anonymized data with the city council without fear of losing their competitive advantage or compromising privacy.
- **Open innovation**: By facilitating access to quality data, the city becomes a laboratory for startups and entrepreneurs who can create applications that solve citizen problems such as accessible route apps or home energy saving systems.

3.1.5 Resilience and crisis management

In emergency situations (floods, fires, health crises), response time is vital.

- **Real-time coordination**: A data space allows emergency services (police, firefighters, ambulances) to instantly access critical data from various sources (cameras, river flow sensors, population density in specific areas) to coordinate a unified and efficient response.

3.1.6 Data sovereignty and control over its use

- In contrast to conventional information exchange models, where data are often lost through sharing, data spaces are based on principles of sovereignty. This means that the data owner retains, at all times, the power to determine who accesses the information, for what purpose, under what conditions, and for what period.

- This approach is fundamental to building trust among ecosystem participants and ensuring responsible data use, especially in sensitive contexts such as urban management.

3.1.7 Sustainability and climate objectives

To meet decarbonization commitments, cities need to measure their environmental impact accurately.

- **Carbon footprint monitoring**: The data space centralizes information on transport emissions, industrial consumption and building efficiency, allowing mitigation policies to be applied where they are most needed and their effectiveness to be measured transparently.

3.1.8 Boosting innovation and the data economy

Data spaces act as catalysts for innovation by facilitating access to rich, diverse, and high-quality datasets. This enables businesses, startups, research centres, and developers to create new digital services, applications, and data-driven solutions.

In an urban context, this can translate into services such as:

- Smart mobility applications.
- Urban planning tools.
- Energy efficiency solutions.
- Citizen participation platforms.

In this way, data spaces contribute to the development of a dynamic economic ecosystem, boosting competitiveness and attracting talent and investment.

3.1.9 Improvement of transparency and citizen participation

Controlled access to urban data promotes transparency in public management and allows citizens to better understand how decisions affecting their environment are made.

Furthermore, data spaces can enable more advanced participation mechanisms, where citizens are not only consumers of services but also generators and co-creators of information. This strengthens trust in institutions and fosters more open and participatory governance.

In this sense, the data space is greatly enriched by enabling the secure integration of citizen-generated data (crowdsourcing and citizen science). By allowing residents to act as active sensors of the city – for example, by voluntarily and anonymously sharing data from their home air quality monitors, pedestrian mobility patterns, or reporting urban incidents – the administration obtains

unprecedented granularity of information. Through the data space, reward or tokenization models can also be established to incentivize this contribution, definitively transforming the citizen from a mere recipient of services into an active, participatory, and sovereign node within the urban digital ecosystem.

3.2 Typical use cases at the local level and their impact on urban management

The primary function of an urban data space is to act as a trusted infrastructure that enables information to flow between traditionally disconnected sectors. This flow facilitates a paradigm shift in urban management, allowing the city to move beyond operating as a collection of independent departments and evolve into an integrated, coordinated, and data-driven decision-making system.

The most relevant and transformative use cases in the local context are detailed below.

3.2.1 Multimodal and sustainable mobility

Urban mobility is one of the areas where data spaces have the most immediate and visible impact. Integrating data from multiple modes of transport allows for optimized planning, reduced emissions, and an improved user experience.

- **Multimode route planning**: Combining real-time data from public transport (buses, metro, commuter rail), shared mobility services (bicycles, electric vehicles, scooters), and road traffic allows for the provision of optimized routes for citizens based on criteria such as time, cost, sustainability, and accessibility. This approach is key to the transition towards integrated multimodal models.
- **Integrated ticketing**: Data spaces enable the seamless exchange of information between operators, facilitating ticketing services on unified platforms. In line with the transition to multimodal routes, single-fare payment per route is a key element for users when planning journeys. For example, a user could pay a single price, once, on a single platform, even if they use public transport, ride-hailing services, or shared micromobility services on the same trip.
- **Dynamic access management**: The management, activation, or dynamic pricing of Low Emission Zones (LEZs) can be achieved by cross-referencing real-time air quality data with vehicle flow to automatically adjust traffic lights, divert traffic, or modify parking rates according to pollution levels.
- **Optimizing public transport**: Analysing demand patterns, origin-destination matrices, modal split, events, and historical data allows for adjusting frequencies, routes, and capacity, improving service efficiency and reducing operating costs, and enabling route planning on demand (MoD).

3.2.2 Urban planning and design, and strategic decision making

The availability of integrated data allows for a significant improvement in urban planning processes at multiple scales of intervention through scenario simulation using digital twins, dynamic modelling with agent-based models (ABM), or the application of spatial analysis methodologies based on GIS.

- **General urban planning** (PGOU, masterplan): Evidence-based urban planning through the evaluation of large-scale strategic scenarios.
- **Partial planning, expansion plans, planning of new neighborhoods**: Evaluation of different urban models, analysis of urban form conditions, and simulation of operation and impact modelling. It allows for comparisons between compact, dispersed, and mixed models, distribution of green areas, connection with other neighborhoods, and so on.
- **Targeted intervention plans**: On existing spaces in urban improvement processes: Evaluation of the functioning of existing spaces and simulation of alternatives for the improvement of access, traffic directions, transport routes, pedestrianization.
- **Evidence-based policy design**: Integrating socioeconomic, environmental and mobility data supports policies aligned with the real needs of the territory, and allows the impact of planning decisions to be assessed before implementation.

3.2.3 Smart logistics

Considering the increasing digitalization of commerce, the rise of parcel delivery apps, and the demand for food and restaurant services through digital platforms, there is a growing volume of parcel delivery operations in cities. In this context, data spaces enable the development of smart solutions that mitigate and prevent the potential negative impacts of these trends. The use of data spaces for sovereign information exchange allows for the creation of innovative business models in the field of urban logistics.

- **White-label consolidation centres**: Secure information exchange between operators enables the use of combined parcel tracking systems, allowing logistics consolidation centres to operate for multiple operators, increasing efficiency in storage and transport spaces, and allowing the use of lighter vehicles.
- **Small-scale consolidation centres (micro-hubs)**: The increased efficiency resulting from the use of shared infrastructure among logistics operators allows for the concentration of goods in smaller, centralized spaces. Currently, micro-logistics hubs avoid medium-distance delivery routes using vans and light trucks, consolidating goods among operators and delivering them on short-distance routes using cargo bikes or micro-vans.
- **Collection points**: White label parcel services: Currently managed by single operators, they could become part of wider networks and be used by various operators.
- **Use of public transport** during off-peak hours for parcel delivery.

- **Shared routes**: Between operators: Derived from the use of consolidation centres, different logistics operators could plan shared routes according to the demand for shipments, thus avoiding redundancy in routes between different operators.

3.2.4 Energy management and decarbonization

Data space is the key tool for cities to achieve climate neutrality by enabling a granular view of consumption and generation.

- **Local energy communities**: Facilitating the exchange of data between neighbors who produce solar energy and the rest of the neighborhood, optimizing collective self-consumption and reducing dependence on the general grid.
- **Efficiency in public buildings**: Monitor and cross-reference building occupancy data (schools, sports centres, offices) with air conditioning consumption to detect energy leaks and automate savings during non-school hours.

3.2.5 Circular economy and waste management

Transform waste management from a "fixed route" service to one based on actual demand.

- **Pick-up on demand**: Use fill sensor data in containers (paper, glass, packaging) shared with the cleaning company to optimize truck routes, saving fuel and reducing nighttime noise.
- **Local industrial symbiosis**: A data space allows companies in an industrial park to share information about their waste, so that the waste of one can be the raw material of another, promoting the circular economy at the municipal level.
- **Waste traceability**: Integrating data across the whole management chain improves control, increases recycling rates and supports compliance with regulatory targets.
- **Intelligent energy network management**: Integrating distributed generation, storage, and consumption data allows progress towards smart grids, which are more resilient and efficient.
- **Energy efficiency in public and private buildings**: Combining data on occupancy, air conditioning, energy consumption, and environmental conditions allows for the identification of inefficiencies, the automation of systems, and the reduction of consumption without compromising comfort.

3.2.6 Smart tourism and flow management

It allows for a balance between the economic benefits of tourism and community life.

- **Visitor redistribution**: Analyse aggregated mobile network data, payment transaction data and presence sensors, processed under an appropriate legal basis, to identify tourist saturation

points and send real-time recommendations to visitors towards less congested areas with cultural interest.

- **Service planning according to the floating population**: Adjust the frequency of cleaning or security in tourist areas based on the forecast of actual influx derived from historical data and hotel bookings.
- **Personalizing the tourist experience**: Data integration allows for personalized recommendations in real time, improving service quality and increasing average spending per visitor.

3.2.7 Social welfare and public health

The use of shared data allows for more proactive and closer management, especially with vulnerable groups.

- **Preventing unwanted loneliness**: Cross-referencing household water or electricity consumption data with social services records to detect anomalous patterns (for example, absence of consumption in an elderly person's home) that may trigger a preventive visit from telecare services. Because this use case links records at individual level, the data involved is pseudonymized rather than anonymized: it must be processed under an explicitly defined legal basis, preceded by a data protection impact assessment, and restricted to the minimum set of attributes needed to raise an alert.
- **Environmental health heat maps**: Relate pollen, noise and pollution sensor data with hospital admission data for respiratory problems to design "healthy routes" or special protection zones near hospitals and senior centres. The same integration supports anticipatory clinical planning, for example by mapping patients with climate-related comorbidities against forecast environmental risk such as heat episodes affecting older residents.
- **Population health intervention**: Aggregated and anonymized consumption patterns (energy, water), combined with public health datasets, can be used to target preventive interventions towards communities at higher risk, rather than to flag individuals. Framing the analysis at cohort level keeps the intervention proportionate and avoids the surveillance dynamic described in section 3.1.
- **Optimization of social and healthcare services**: Data integration allows for improved coordination between social and health services, optimizing resource allocation and improving citizen care.

3.2.8 Urban security and emergency management

Data spaces allow for a faster, more coordinated, and more effective response to critical situations.

- **Comprehensive emergency management**: Integrating data from multiple sources (sensors, emergency services, traffic) allows for better coordination and reduced response times.

- **Predictive risk analysis**: The use of predictive models allows us to anticipate risk situations such as floods, fires, or security incidents.

3.2.9 Promotion of innovation and local economic development

Beyond internal management, data spaces have a direct impact on the economic ecosystem.

- **Development of new digital services**: Companies and startups can develop innovative solutions using urban data, generating new business models.
- **Attracting investment and talent**: Cities with advanced data infrastructures position themselves as attractive environments for innovation and technological investment.

3.3 Alignment with sustainable city goals

An Urban Data Space is the invisible engine that allows cities to align their growth with planetary boundaries and social needs. In the current context of climate crisis and accelerated urbanization, this ecosystem is not a technological luxury, but a tool for institutional survival. This alignment extends to the United Nations Sustainable Development Goals and to the commitments on data governance and digital inclusion set out in the Global Digital Compact.

Its main function in relation to sustainability is to transform municipal management from a model based on "consumption and reaction" to one based on "efficiency and regeneration".

The following details how the data space specifically aligns with the goals of a sustainable city:

3.3.1 Decarbonization and energy efficiency

Urban sustainability begins with the ability to measure the carbon footprint in real time. A data space enables:

- **Smart grid optimization**: By sharing data between energy providers and the city council, electricity loads can be adjusted, reducing waste and facilitating the integration of local renewable energy (solar panels on public buildings or energy communities).
- **Building management**: It cross-references data from temperature and occupancy sensors to optimize climate and lighting. A building that "knows" when it is empty and turns off its systems saves up to 30 per cent on energy, directly contributing to net-zero emissions goals.
- **Real-time data-based energy management**: Through the integration of IoT sensors and BMS systems, predictive control strategies (model predictive control, MPC) are implemented to optimize air conditioning, lighting and electricity consumption in public and private buildings.

- **Digitized carbon accounting**: The UDS allows the calculation of operational carbon footprints (Scope 1, 2 and partially Scope 3) at the urban level, facilitating evidence-based decarbonization policies.

3.3.2 Low emission mobility and improved air

Mobility is responsible for a large part of urban pollution. Alignment here is critical:

- **Dynamic Low Emission Zones (LEZs)**: The data space allows traffic restrictions to be not a fixed measure, but an intelligent one. If air quality sensors detect a high concentration of particles, the system can automatically trigger alerts, increase the frequency of public transport, and suggest alternative routes.
- **Reduction of "agitation mobility"**: Sharing real-time parking data reduces the time drivers spend circling in search of a parking space, drastically decreasing unnecessary CO2 emissions in the city centre.
- **Reduction of search-induced traffic**: Integrating real-time parking data minimizes unnecessary cruising traffic, reducing emissions and energy consumption.
- **Multimodal integration**: The UDS enables interoperability between public transport, micro-mobility and shared mobility, optimizing the efficiency of the overall system.

3.3.3 Circular resource management

A sustainable city is one that stops generating waste and starts managing resources. Data space facilitates the circular economy.

- **Smart water management**: Integrating supply network data with weather models allows for the instant detection of invisible leaks and the optimization of park irrigation based on actual soil moisture, preserving a resource as scarce as water.
- **Waste traceability**: It allows waste generators to be connected with potential re-users within the same city, closing the life cycle of materials and reducing the need for landfills.
- **Urban industrial symbiosis**: connecting surpluses and demands for materials between urban actors to close production cycles.

3.3.4 Climate resilience and adaptation

Sustainable cities must be able to withstand extreme weather events.

- **Risk prevention**: A data space that integrates information on riverbeds, sewer levels, and weather forecasts allows for the creation of early warning systems for floods, protecting infrastructure and human lives.

- **Heat island mitigation**: By analysing thermal data cross-referenced with vegetation maps, the data office can identify which neighborhoods urgently need "green corridors" or vegetation cover to lower ambient temperatures, improving public health.
- **Multirisk early warning systems**: Integration of meteorological, hydrological and urban data for the detection of floods, heat waves or extreme events.
- **Modelling urban climate scenarios**: Use of urban digital twins to simulate the impacts of extreme events on critical infrastructure.

3.3.5 Urban governance, transparency and social sustainability

Social sustainability is the third pillar of sustainable development. The data space democratizes information.

- **Environmental accountability**: By making sustainability data public (consumption, emissions, recycling), citizens feel part of the process and the administration is forced to fulfill its environmental commitments.
- **Incentives for sustainability**: It allows the creation of "green points" programmes or tax incentives for those citizens or businesses that demonstrate, through data, responsible behavior towards the environment.
- **Algorithmic transparency and open data ecosystems**: Publication of urban indicators in real time to facilitate accountability.
- **Evidence-based governance**: Support for public policies through advanced analytics and continuous impact assessment.
- **Mechanisms for data-driven citizen participation**: Platforms that allow citizens to interact with urban data, co-create solutions and participate in co-governance.
- **Behavioral incentive systems**: Implementation of data-driven "urban nudge" models to encourage sustainable behaviors (recycling, active mobility, reduced energy consumption).

4 The Process of Integrating a City Platform into a Data Space

4.1 Platform integration

Integrating a city platform into a data space is a progressive and structured process that connects the local entity's information assets with a broader environment for data exchange, reuse, and exploitation. This process is not solely technological; it also involves organizational, legal, and governance aspects that must be addressed in a coordinated manner. Typical phases of the process.

A city platform data governance framework must be in place first, to define the rules of the game in the context of interaction with data spaces. After that in this overarching data governance framework we can integrate governance models and policies connected to each specific data space. In addition to that, data quality framework for the city platform must be defined, incorporating multiple dimensions of data quality; for example, accuracy, validity, completeness, consistency, uniqueness and timeliness.

The integration process usually unfolds through a series of common phases, which help reduce risks, ensure overall coherence, and facilitate controlled evolution:

- **Initial analysis and strategic alignment**: In the first phase, the local entity's objectives regarding its participation in a data space are identified, analysing the expected benefits, priority use cases, and the maturity level of the city's platform. This analysis ensures alignment with digitalization strategies, data governance, and inter-institutional collaboration.
- **Inventory and valuation of data assets**: An inventory is taken of the information sources, datasets, and services available on the city platform, evaluating their quality, level of structuring, sensitivity, and potential for reuse. This phase is key to determining what data can be shared and under what conditions.
- **Technical and semantic suitability**: This phase addresses the aspects necessary to guarantee interoperability with the data space, including the adoption of common data models, semantic alignment, the use of ontologies, the definition of interfaces, and the suitability of access and security mechanisms.
- **Definition of the governance model and conditions of use**: The rules governing the city platform's participation in the data space are established, defining aspects such as the roles of data provider and consumer, access conditions, usage agreements, information protection, and monitoring mechanisms.
- **Progressive integration and commissioning**: The integration is done incrementally, starting with a limited set of data or services, which allows for the validation of the defined mechanisms and adjustments to be made before extending the integration to other areas of the city.
- **Monitoring, continuous improvement and evolution**: Once the integration is operational, monitoring and evaluation mechanisms are established to measure the use, impact and value generated, facilitating the evolution of the model and the incorporation of new use cases or actors.

All these phases assume increased workload compared to existing processes from the data space representatives. This means extra costs and potential resistance, which must be taken into account.

4.2 Actors involved inside and outside the local entity

Integrating a city platform into a data space involves the participation of multiple actors, internal and external to the local entity, each with differentiated responsibilities.

Actors within the local entity include:

- **Governing and management bodies**: Responsible for defining the strategy, approving the participation framework and ensuring alignment with institutional objectives.
- **Municipal service management areas**: Producers and users of the data, responsible for ensuring the quality, updating and suitability of the information for the intended purposes.
- **Information technology services**: Responsible for the architecture, technical integration, security and operation of the platform.
- **Legal and data protection areas**: responsible for ensuring regulatory compliance, privacy and the proper regulation of the use of information.
- **Data governance units** (where they exist): Responsible for coordinating policies, standards and processes related to information management.

Actors outside the local entity includes:

- **Supramunicipal administrations:** Provincial councils, island councils, autonomous communities or state bodies that participate in common data spaces or provide shared infrastructures.
- **Other public entities**: that act as consumers or providers of data in the shared space.
- **Concessionary companies and urban service providers**: Generate or consume information relevant to the management of the city.
- **Technology providers and data space operators**: Responsible for the infrastructures, platforms and services that support the exchange of information.
- **Innovative ecosystem and authorized third parties**: Companies, research centres or entities that reuse data to develop value-added services, under the established conditions.

The process of integrating a city platform into a data space should be understood as a collaborative and evolving effort, in which the local entity plays a central role as guarantor of the public interest, the proper use of information, and the generation of value for society, the correct definition of the phases and the actors involved is key to ensuring effective and sustainable integration aligned with the territory's strategic objectives.

4.3 Organizational, legal and governance aspects

Integrating a Smart City Platform into a Data Space represents a critical transition from isolated information systems to federated ecosystems. This process is not merely a technical upgrade; it is an institutional re-engineering that demands a precise balance between data sovereignty, interoperability, and regulatory compliance.

The organizational, legal, and governance pillars that support this deployment are then analysed.

4.3.1 Ecosystem governance: the trust framework

Governance in an urban data space defines the rules of the game for asset sharing between public and private actors. Unlike traditional data management, this approach seeks decentralized governance.

- **Authority models**: It is necessary to create a Data Governance Office or a governing consortium that acts as a certification authority. This entity defines the levels of adherence and the trust frameworks.
- **Usage control policies**: This is the core of technical governance. This is not just about who has access, but also what actions are permitted. Policies of mandatory, prohibited and permitted access are implemented, and linked to the data through active metadata.
- **Federated identity management**: Governance must validate the identity of participants (nodes) using protocols such as DAPS (Dynamic Attribute Provisioning Service), ensuring that only authorized entities exchange information within the space.

4.3.2 Legal framework and regulatory compliance

The integration process must navigate a complex legislative framework, especially in the European context, where digital sovereignty is a strategic priority.

- **Alignment with the Data Governance Act (DGA) and Data Act**: These regulations govern the reuse of protected data and the obligation to share data generated by IoT devices. The platform must implement legal mechanisms for data mediation and the management of intermediary services.
- **Personal data protection (GDPR)**: Integration requires the use of Privacy Enhancement Techniques (PETs). The roles of "Controller," "Processor," and, in many cases, "Joint Controller" for the processing of data flowing through the space must be formalized.
- **Smart contracts**: To automate legality, the terms of use are codified. These digital contracts ensure that data transactions comply with pre-established licenses in an auditable manner and without constant human intervention.

4.3.3 Organizational aspects and structural change

Technical integration will fail if the city's organizational structure does not evolve towards a data-driven culture.

- **Organizational interoperability**: This involves aligning business processes across different municipal departments (mobility, energy, waste). Each department retains ownership of its data and assumes, in addition, an explicit stewardship duty. Ownership is not transferred to the platform – this would contradict the principle set out in section 2.3 that control remains with the

data holder. What changes is that departments become accountable for data quality, access rules and privacy safeguards, supported by visible quality metrics and by guidance from the Data Office.

- **Profiles and capabilities**: There is a need for the institutionalization of figures such as the urban Chief Data Officer (CDO) and data analysts who understand not only the technique, but also the public value of the data.
- **Sustainability and business models**: From an organizational standpoint, the city must decide whether to act as a neutral node, a premium data provider, or a market facilitator. This involves defining cost structures for maintaining the federated infrastructure and potential incentives for private sector participation.
- **Change management and adoption**: Adoption plans built around training alone may not address resistance and may not guarantee use. Planning for change in advance – communication, addressing stated concerns, securing buy-in from the actors involved, coordinating training, and establishing incentives that outlast the project – is a condition of successful implementation.

4.3.4 Reference architecture and semantic interoperability

For organizational and legal aspects to be effective, they must "land" in a coherent technical architecture such as FIWARE standards or the DSBA (Data Spaces Business Alliance).

- **Nodes and connectors**: The city platform is integrated through connectors (e.g., Eclipse Dataspace Components - EDC). These components are responsible for applying governance and legal rules at the precise moment of the exchange.
- **Shared vocabularies**: The organization must adopt standard ontologies (such as SAREF for energy or GTFS for transport) to ensure that the meaning of the data is the same for all participants in the data space, eliminating ambiguity in the interpretation of policies.

In conclusion, the successful integration of a city platform into a data space requires that technology be at the service of a solid legal framework and a flexible organization, ensuring that urban data generates public value without compromising the security or sovereignty of citizens.

5 The Data Office: Concept and Functions

5.1 What is a data office?

The Data Office (DO) is a cross-cutting organizational unit responsible for the strategic, operational and ethical governance of the complete data lifecycle in a complex organization, particularly in the context of public administrations and smart urban ecosystems.

From a socio-technical systems perspective, the DO acts as a coordination node between technological infrastructure, administrative processes and evidence-based decision-making, thereby ensuring that data are treated as a high-value strategic asset and not as a residual byproduct of administrative operations.

Within the framework of data-driven cities, its function transcends traditional IT management, positioning itself as an urban knowledge governance body, responsible for enabling digital transformation oriented towards sustainability, institutional efficiency and public innovation.

The Data Office is situated at an intermediate level between senior public management (strategy and public policies) and technical units (information systems, sensors, digital platforms), functioning as a mediating layer between the political dimension and the digital infrastructure.

Its role can be described as that of an institutionalized "data governance layer", with the capacity to:

- Define corporate data policies.
- Establish technical and semantic standards.
- Coordinate internal and external actors in the data ecosystem.
- Ensure traceability, quality, and reuse of information.

In this sense, it aligns with international frameworks such as the European Data Governance Act, the Common European Data Spaces architecture and reference models such as FIWARE or GAIA-X.

5.1.1 The pillars of the data office - functional architecture

To fulfill its purpose, the Data Office relies on four fundamental pillars:

Governance and ethics (Data Governance)

It is responsible for defining who can do what with which data. It establishes access, security, and privacy policies, ensuring strict compliance with legal frameworks (such as the GDPR) and ethical principles. Its role is to guarantee that the use of information is transparent and that citizens' identities are always protected.

- Definition of policies for access, use, sharing and reuse of data.
- Establishment of data ownership, sovereignty and stewardship models (data ownership vs data stewardship).
- Design of regulatory compliance frameworks (GDPR, ENS, ISO/IEC 27001, ISO 38505, EN 18235 on trusted data transactions).
- Implementation of audit and traceability mechanisms for data use.

Quality and Interoperability

Incorrect data lead to incorrect decisions. The office establishes technical and semantic standards to ensure that data are accurate, up-to-date, and, above all, interoperable. This means that data from different departments (health, transport, urban planning) must be able to be combined without technical errors to provide a 360-degree view of the city.

- Definition of data quality standards (completeness, consistency, accuracy, currency).
- Implementation of data cleansing and automated validation processes.
- Development of interoperability models based on APIs, ontologies, and semantic models.
- Normalization of data structures using open standards (ITU, ISO, CEN EN 18235, W3C, FIWARE NGSI).

Data culture (data literacy) - Advanced analytics

One of the office's biggest challenges is cultural change. The office must train public employees and managers to understand the value of data and learn to use analytical tools in their daily work, breaking the inertia of making decisions "by intuition."

Beyond technical training, the main obstacle to effective governance is often departmental reluctance to share information, stemming from the perception of data as the exclusive property of their department rather than a corporate asset. Therefore, the Data Office plays a critical role in change management and internal advocacy, acting as a facilitator to mitigate this fear of relinquishing control. Its mission is to demonstrate that contributing data to a shared, trusted environment does not diminish authority but rather multiplies value and efficiency for the entire organization.

- Development of descriptive, predictive, and prescriptive analytical models.
- Implementation of artificial intelligence and machine learning systems for decision support.
- Construction of urban simulation models and digital twins.
- Integration of real-time analytics for operational management of urban services.

Architecture and technology

Although it doesn't always manage the servers, the office defines the technology strategy: from the implementation of the City Platform to the creation of the Data Space. It decides which artificial intelligence or advanced analytics tools are needed to process the information.

5.1.2 Main Functions

An active Data Office performs the following critical functions:

- **Inventory and cataloguing**: Create a single data catalogue to know what information exists in the city hall and where it is located.
- **Data space management**: Facilitate the secure exchange of information with external actors (companies, universities, other administrations).
- **Predictive analytics**: Develop models that allow anticipating problems such as pollution peaks, traffic congestion, or infrastructure maintenance needs.
- **Promoting open data**: Publish datasets in open formats so that civil society and businesses can reuse them, promoting transparency and the digital economy.

5.1.3 Why is it necessary in a city?

Traditionally, cities have operated in silos. The water department didn't know what the public works department was doing, and the transportation department didn't share its data with the environmental department. This fragmentation leads to inefficiency and duplicated spending.

The Data Office eliminates these silos. By centralizing strategy, it enables:

1) **Cost savings**: By optimizing service routes and detecting unnecessary consumption.
2) **Administrative agility**: Reducing bureaucracy through the automation of processes based on real data.
3) **Improving citizens' lives**: Public services adapt to real demand, not to a theoretical estimate.

5.1.4 The Office Profile: The role of the Chief Data Officer (CDO)

At the head of this office is the Chief Data Officer (CDO). Their profile is hybrid: not only must they understand the technical complexities of Big Data and AI, they must also possess the political and management skills to coordinate the various municipal departments. Their goal is not for the city to have "more technology," but for the city to be better informed and more sustainable.

5.1.5 Key role in urban data spaces

In the context of data spaces, the Data Office acquires a critical structural function, as it acts as a guarantor of trust, interoperability, sustainability and, where the city chooses to operate one, of the data marketplace described in section 2.2.4.

Governance and trust

- It establishes governance frameworks for data exchange among multiple actors.
- It guarantees data sovereignty through decentralized control models.
- Define policies for security, privacy, and ethical use of information.

Without this function, data spaces degrade into fragmented repositories with no systemic value.

Technical and semantic interoperability

- Implement common data and metadata standards.
- Coordinates the adoption of shared ontologies.
- It ensures compatibility between heterogeneous systems.

This allows for the construction of a common language for urban data.

Regulatory compliance and data ethics

- Ensure compliance with GDPR and data protection regulations.
- Oversees anonymization and pseudonymization processes.
- It guarantees the traceability of data flows.

This positions the DO as an institutional mechanism for ethical data control.

Energizing the data ecosystem

- Identify high-impact use cases for the city.
- It facilitates the participation of companies, startups and universities.
- It promotes the creation of innovative, data-driven services.

This transforms the data space into a productive ecosystem for urban innovation.

Integration between urban platform and data space

- It ensures the bidirectional flow of data between operational and analytical systems.
- It coordinates the integration between urban IoT infrastructure and shared data platforms.
- Monitor data quality throughout the entire lifecycle.

This allows for an urban architecture in which operation and intelligence are continuously fed back into each other.

5.2 Why it's key in data spaces

This section describes the critical and strategic role of the Data Office (DO) as a cornerstone in the architecture, deployment and sustainability of Data Spaces.

In an environment where information flows beyond the boundaries of a single organization, the Data Office ceases to be a mere internal manager and becomes the guarantor of trust and the architect of interoperability. Without its involvement, data spaces risk becoming disconnected, insecure, or worthless repositories of information.

The following details the fundamental reasons that explain its key role:

5.2.1 Establishing the governance and trust framework

A data space is not a centralized database, but an ecosystem where multiple actors (public and private) share information. The Data Office is essential because:

- **Define the rules of the game**: It establishes usage policies, access levels, and conditions under which information can be exchanged.
- **Guarantee data sovereignty**: It ensures that participants maintain control over their assets, implementing the necessary protocols so that the data are not used for purposes other than those agreed upon.
- **Identity and security management**: It acts as the entity that validates the identity of the participants and ensures that the exchange complies with cybersecurity standards and the corresponding national security scheme.

5.2.2 Orchestration of semantic and technical interoperability

For a city council's data to be integrated with that of a transport or electricity company in a shared space, they must "speak the same language." The Open Data Platform (DO) is key to:

- **Model standardization**: It promotes the use of common ontologies and vocabularies (such as the FIWARE model or ITU, ISO standards) that allow heterogeneous systems to understand each other without manual human intervention.
- **Unified data catalogue**: It maintains an up-to-date and descriptive inventory (metadata) that allows other actors to know what data are available, what its quality is, and how it can be consumed through APIs.

5.2.3 Guarantee of ethics and regulatory compliance

In urban data spaces, information often affects citizens' privacy. The Data Office acts as an ethical safeguard.

- **Privacy by design**: It oversees the anonymization and de-identification processes so that the data shared in the common space never puts the individual's identity at risk, strictly complying with the GDPR.
- **Transparency**: It ensures that the flow of data is auditable, allowing society to know how information is being used to generate public value.

5.2.4 Ecosystem dynamization and data valorization

An empty data space is useless. The Data Office assumes a dynamic role:

- **Use case identification**: It detects which combinations of data (e.g., climate + mobility + health) can solve critical city problems, driving pilot projects within the data space.
- **Promoting the data economy**: It facilitates access to high-quality data for local businesses and startups to create new services, acting as the link between the needs of the administration and the innovation capacity of the private sector.

5.2.5 The role of "orchestra conductor" in technical integration

The Data Office ensures that the City Platform (operational) and the Data Space (collaborative) function in a synchronized manner:

- **Bidirectional data flow**: It ensures that the data captured by the city's sensors feeds into the shared space and, in turn, that the intelligence generated in the data space returns to the platform to improve municipal services.
- **Quality supervision**: It establishes cleaning and validation processes to ensure that the data entering the shared ecosystem is truthful, complete, and useful.

5.3 Integration with the city ontology in terms of governance

The integration of the Data Office (DO) with the City Ontology represents the union between political/strategic will and technical architecture. In governance terms, this relationship is what allows a city to move from managing "archives" to managing "shared knowledge."

The following section describes in detail how this integration acts as the engine of modern urban governance.

5.3.1 Ontology as the "Semantic Constitution" of governance

In the realm of governance, a city ontology is not merely a data model; it is a formal agreement defining the meaning of each element of the city (an asset, a citizen, an event, a service). The Data Office uses the ontology to establish a "Constitution" that all departments must adhere to.

- **Unification of concepts**: The DO integrates the ontology to prevent the urban planning and finance departments from having different definitions of "housing" or "land." Governance becomes coherent because all administrative actors operate on a single conceptual basis.
- **Technological neutrality**: By integrating a standard ontology (such as SAREF or ETSI CIM), the DO ensures that governance does not depend on a specific software provider, guaranteeing the municipality's long-term technological sovereignty.

5.3.2 Quality control and veracity (Data Stewardship)

Governance requires that data be reliable. Integration with the ontology allows the Data Office to automate the validation of information entering the system.

- **Business rule validation**: The ontology defines the logical relationships (for example: "an air quality sensor must be linked to a geographic location"). The DO integrates these rules into its governance processes to automatically reject any data that do not comply with the ontological structure, thus ensuring the integrity of the Data Space.
- **Traceability and lineage**: Thanks to the ontology's structure, the DO can trace the origin of each piece of data, who modified it, and under what legal basis. This is fundamental for auditing public processes.

5.3.3 Context-based access and security governance

One of the most critical aspects of the Data Office is deciding who has access to what. Integration with the ontology allows for much more sophisticated governance than traditional "username and password" permissions.

- **Semantic access policies**: Instead of granting access to "tables," the DO defines permissions based on ontological classes. For example, it can be stipulated that "only social services managers can view data from the 'Vulnerable Person' class."
- **Dynamic anonymization**: The ontology helps identify which attributes are sensitive (personal data) within an urban context, allowing the DO to apply governance rules that automatically anonymize information before it goes out into the Open Data Space.

5.3.4 Automation of interoperability between departments

Traditional governance often fails due to the bureaucracy of sharing data between silos. Integrating the DO with the ontology eliminates this friction.

- **Data discovery**: The ontology acts as an intelligent catalogue. The Data Office can "ask" the system what data exists about a concept (e.g., "Nighttime Noise") and the ontology will automatically connect sources from the local police, environmental sensors, and citizen complaints.
- **Flow Mapping**: The DO uses ontology to map how information flows between the different verticals of the city (City Platform) and external actors (Data Space), ensuring that data exchange contracts are fulfilled in an automated way.

5.3.5 The role of the "Ontology Manager" within the office

For this integration to be effective, the Data Office structure incorporates a new governance role: the Ontology Manager. Their function is:

1) **Evolve the model**: Ensure that the ontology grows according to the new needs of the city (e.g., integration of electric mobility data).
2) **Governance of Consensus and Sharing Agreements**: Acting as a mediator between different departments, not only to reach agreements on how new urban services should be modelled, but also to establish and formalize internal data-sharing agreements. This means that the Data Office drafts agreements between departments (for example, between urban planning and mobility) explicitly defining what data are shared, how frequently, for what specific use cases, and under what privacy rules, thus institutionalizing trust beyond the technological layer.

Integration summary

Integrating the Data Office with the city ontology transforms governance from a manual and documentary task into model-driven governance.

Table 3: Contribution of the city ontology to data governance

Governance dimension	The role of ontology	Data Office action
Regulations	Define the official dictionary of the city.	It requires compliance with the standard in all technical specifications.
Operation	Establish the logical relationships between assets.	Automate the integration of silos and services.
Security	Classify the sensitivity of the information.	It applies context-based privacy policies by design.

Governance dimension	The role of ontology	Data Office action
Strategic	It allows complex cross-queries.	Make decisions based on multidimensional evidence.

This synergy ensures that the Data Space is not just a technical infrastructure, but a governed, ethical, and semantically coherent environment where information becomes a true public service.

5.4 Main functions and responsibilities

The Data Office (DO) has established itself as the nerve centre of modern urban strategy. Its existence responds to the need to professionalize information management, moving from a model where data were "files stored in departments" to one where they are interconnected strategic assets.

To understand its scope, it is necessary to break down its functions and responsibilities into four critical areas: strategic, regulatory, operational, and dynamic.

5.4.1 Strategic functions: the course of data

The Data Office defines the city's "north" in terms of information. Its responsibility is not only technical, but also involves a long-term vision.

- **Data strategy definition**: Define the city's long-term approach to how data are collected, managed, governed, shared, protected and used to create value, and how it supports the city's goals, decision-making, operations, innovation and digital services, aligning this with the objectives of sustainable development and urban efficiency.
- **Change management and culture (data literacy)**: It is responsible for fostering an evidence-based culture within the public administration. This includes training managers and technical staff to interpret data in their daily decision-making.
- **Leadership in the Data Economy**: To act as an intermediary with the business and academic ecosystem to identify how public data can generate wealth, employment and innovation in the private sector.

5.4.2 Regulatory and governance functions: the ethical framework

This is perhaps the most delicate function, as it protects the rights of citizens and the integrity of the institution.

- **Establishing governance policies**: Define who owns (custodian) each piece of data, who has permission to access it, and for what specific purposes.

- **Privacy and ethics guarantee**: Monitor that all data processing activities comply with the GDPR and, where applicable, the EU Artificial Intelligence Act and equivalent national AI frameworks, as well as ethical standards, ensuring that technology is never used for mass surveillance or discriminatory bias.
- **Data quality management**: Establish standards for truthfulness, accuracy, and currency. The Office is responsible for ensuring that data are not "dirty" or outdated, which would invalidate any subsequent analysis.

5.4.3 Operational and technical functions: the engine of integration

This is where the Data Office gets its hands dirty with information infrastructure and architecture.

- **Data catalogue administration**: Maintain a centralized and documented inventory (metadata) of all information available in the city council and its dependent entities.
- **Interoperability and semantic standardization**: Responsibility to ensure that data from different sources (traffic, energy, social services) use common languages and formats (such as city ontologies) so that they can be cross-referenced without errors.
- **Deployment of advanced analytics and AI**: Oversee the development of predictive models and algorithms that allow the city to anticipate problems (such as pollution spikes or public utility overflows).

5.4.4 Dynamic functions: the connection with the outside

The Data Office is not a bunker; it is an open window that connects the municipal platform with the world.

- **Promoting open data**: Select, prepare and publish high-value datasets in reusable formats so that journalists, developers and citizens can consult them transparently. Publication carries a maintenance commitment: each dataset should declare an update frequency and a deprecation policy, and should be exposed through documented programmatic interfaces consistent with the connector model described in section 2.2, so that reuse does not depend on manual downloads.
- **Data space management**: Act as the "referee" and facilitator in the exchange of information with external actors (other administrations, public service companies, universities), ensuring that the flow of data is secure and reciprocal.
- **Use case identification**: Actively seek out urban problems that can be solved by cross-referencing data, designing pilot projects that demonstrate the real value of shared information.

Table 4: Responsibilities of the Data Office

Responsibility	Detailed description
Custody of truth	Ensure that the information used in public management is accurate and comes from reliable sources.
Citizen protection	To ensure the anonymity and security of personal data throughout the data lifecycle.
Exchange architecture	Design the technical and legal bridges to allow data to flow between the administration and external agents.
Value maximization	Ensure that every bit of information generated has a purpose that improves the quality of life or economic efficiency.

6 The Role of the Data Office in Integration into a Data Space

6.1 Internal municipal coordination

Creating a Data Space is not simply a technological project; it's a structural transformation in how an organization operates and shares information. In the public sector, the Data Office (DO) acts as the architect and conductor of this ecosystem.

Next, let's detail how this figure facilitates integration into these spaces and, more specifically, how it manages the complex network of internal municipal coordination.

6.1.1 The role of the Data Office in the data space

A data space is a federated ecosystem where participants share information securely, sovereignly, and under common rules. The Data Office (DO) is the entity responsible for ensuring that the municipality is not just a file "repository," but an active and efficient node.

- **Governance and strategy**: Define the rules of the game. Establish who can access what, under what conditions, and with what levels of security.
- **Semantic interoperability**: It ensures that data from different departments "speaks the same language." If urban planning defines a "street" differently than social services, the data observatory standardizes these concepts so that the data can be integrated.
- **Ensuring sovereignty**: Implement technical connectors (such as those based on IDS or Gaia-X standards) that allow the city council to maintain control over its data even after sharing it.

6.1.2 The internal municipal coordination: the heart of the DO

The biggest challenge for a city council is not technology, but administrative fragmentation. Each department (Mobility, Finance, Environment) tends to operate in isolation. This is where the internal coordination work of the Office of Design becomes critical.

Breaking Down Departmental Silos

The Data Office (DO) acts as a neutral mediator. Its role is to convince area managers that relinquishing control of "their" data to integrate it into a common space is not a loss of power, but rather a gain in administrative intelligence.

- **Asset identification**: Conduct a cross-sectional inventory to find out what data exists in every corner of the town hall.
- **Prioritizing use cases**: Coordinates the areas to decide which data are most urgent to integrate (for example, cross-referencing traffic data with air quality sensors).

Establishment of the "Data Custodians" network

For coordination to be effective, the DO usually appoints or identifies key figures in each department. Responsibilities may be delegated across these roles; accountability remains with the data owner.

1) **Data Stewards**: Technicians within each area who know the origin and quality of the data.
2) **Data Owners**: Political or managerial officials who validate the ethical and legal use of information.

Standardization of internal processes

Municipal coordination involves creating a data "Style Guide." The DO defines protocols for:

- **Data quality**: Prevent duplicate or erroneous data from entering the central system.
- **Privacy by design**: Coordinate with the Data Protection Officer (DPO) to ensure that any internal integration complies with the GDPR from the very first second.

6.1.3 Benefits of robust internal coordination

When the Data Office manages to effectively coordinate the municipal interior, the city council undergoes a metamorphosis:

Table 5: Impact areas of internal municipal coordination

Area of Impact	Result of the coordination
Operational efficiency	Bureaucratic requests for data between departments are eliminated; information flows automatically.
Decision making	The Mayor or the Councillors have a comprehensive dashboard with cross-referenced data from the entire city.
Transparency	It facilitates the opening of data (Open Data) to citizens in a coherent and up-to-date manner.
Public-private collaboration	By having its internal structure in order, the municipality can participate in sectoral data spaces (tourism, logistics, energy) with private companies.

6.2 Relationship with the data space

The creation of a data space represents a paradigm shift: we move from closed systems to federated ecosystems where information flows securely, sovereignly, and in a standardized manner. In this context, the Data Office (DO) ceases to be a mere manager of internal repositories and becomes the gateway and guarantor of the organization's participation in these shared environments.

The multifaceted role of the DO in its relationship with the data space is detailed below.

6.2.1 The role of the DO as a connectivity architect

Integration into a data space (such as those promoted by GAIA-X or IDSA) requires a technical and regulatory infrastructure that the DO must lead.

- **Connector implementation**: The DO oversees the deployment of the technical connectors. These are not simple APIs; they are components that ensure data are used only for the agreed-upon purpose, maintaining data sovereignty.
- **Alignment with European standards**: The DO acts as a watchdog, ensuring that the internal architecture is compatible with frameworks such as the Data Governance Act and the reference models of the European Data Spaces (e.g., health, mobility, energy).
- **Identity and trust management**: It is responsible for the certification of the organization within the ecosystem, managing the credentials that allow other participants to trust that the data provided is truthful and secure.

6.2.2 The DO as curator and translator (Interoperability)

For two organizations to share data, they must understand each other. The DO is responsible for semantic interoperability.

- **Data modelling**: Define and adapt internal data models to industry standards. If the data space uses a specific vocabulary (for example, Schema.org or Datex II for transport), the DO translates the internal structure into these common languages.
- **Metadata enrichment**: Data without context are worthless in a shared space. The DO ensures that every information asset is perfectly catalogued with descriptive, technical, and legal metadata, thereby making it easier for other members of the ecosystem to "discover" the data.

6.2.3 Governance and sovereignty: Controlling the flow

The relationship with the data space is not a simple "file upload," but a regulated exchange. The Data Office (DO) is the department responsible for protecting the organization's interests.

- **Definition of usage policies**: Usage policies – expressed as machine-readable contracts (for example in ODRL) and, in the European Union, framed by the Data Governance Act (DGA) – set the conditions under which data are shared. For example: "This data can be used for academic research free of charge, but requires payment if used for commercial purposes."
- **Access control and traceability**: It monitors who accesses what and for what purpose. In a data space, the Data Office (DO) must be able to audit that the terms of use are being met, protecting intellectual property and data privacy.
- **Risk management and compliance**: It acts as a bridge with the DPO (Data Protection Officer) and the cybersecurity teams to ensure that the output of data to the common space does not compromise sensitive information or personal data.

6.2.4 Dynamization and valorization: The DO as a business node

Beyond the technical aspects, the Data Office has a strategic mission in its relationship with the ecosystem:

1) **Identification of valuable assets**: Analyse which internal data have the potential to be monetized or exchanged for other valuable assets within the data space.
2) **External data consumption**: It is not just about giving, but also about receiving. The DO identifies external data sources within the ecosystem that can improve internal processes, decision-making, or the development of new services.
3) **Promoting a culture of data**: Internally, the DO educates different departments about the opportunities offered by participating in the data space, eliminating the fear of sharing and fostering a collaborative vision.

6.2.5 Vertical inter-administrative coordination

To prevent the municipality from operating as a "digital island" disconnected from its surrounding territory, the local Data Office assumes the responsibility of establishing mechanisms for coordination and vertical federation. This involves actively aligning its governance policies, vocabularies, and architectures with the guidelines of higher-level Data Offices (such as those of its respective Autonomous Community or the Spanish Data Office - SEDIA). This institutional interoperability is essential for urban ecosystems to integrate seamlessly into national or European data spaces (for example, tourism, mobility, or energy networks), multiplying the public value of data and facilitating access to flagship projects and joint funding frameworks.

Table 6: Summary of Key Functions

Dimension	Function of the Data Office
Technique	Deployment of connectors and ensuring interoperability.
Legal/ethical	Ensuring sovereignty and regulatory compliance (GDPR, DGA).
Strategic	Selection of use cases and search for synergies in the ecosystem.
Operation	Catalogue maintenance and shared data lifecycle management.

In short, the Data Office is the body that allows an organization to move beyond being an information island and become a vital and secure hub within the modern data economy. Its success lies in balancing openness to the outside world with internal control and security.

6.3 Governance, quality and use of data

The Data Office (DO) is established as the central governing body that ensures data are treated as a strategic asset and not merely as a technical byproduct. Its mission, within the triad of Governance, Quality, and Use, is to transform the chaos of raw information into a structured, reliable, and actionable resource for decision-making.

The following details their role in each of these fundamental pillars:

6.3.1 Data governance: the control framework

Data governance is the exercise of authority and control over the management of data assets. The Data Office (DO) acts as the legislative and executive body for this framework.

- **Definition of policies and standards**: The DO establishes the "rules of the game." This includes defining who owns each piece of data (Data Owner), who is responsible for its maintenance (Data Steward), and what levels of access are permitted.

- **Lifecycle management**: It monitors data from its creation or capture to its archiving or deletion, ensuring that legal and security requirements are met at each stage.
- **Security and compliance**: It collaborates closely with the cybersecurity and legal departments to ensure that the processing of information complies with regulations such as the GDPR or the Data Governance Act.
- **Data catalogue**: The DO builds and maintains the centralized inventory of metadata, allowing any member of the organization to know what data exists and what it means.

6.3.2 Data quality: the filter of truthfulness

Having access to millions of records is useless if they are duplicated, incomplete or outdated. The Data Office (DO) is ultimately responsible for ensuring the "purity" of the asset.

- **Establishing quality dimensions**: The DO defines the metrics under which the data will be measured: accuracy, completeness, consistency, integrity, timeliness, and validity.
- **Monitoring and profiling**: Implement automated processes that analyse datasets in real time in order to detect anomalies. For example, to identify if there are records with future dates in a "Date of Birth" field.
- **Cleaning and purification processes**: Coordinate corrective actions when errors are detected, ensuring that the cleanup is done at the original source and not just in the final report, preventing the error from spreading.
- **Data lineage**: Data traceability (DO) tracks the origin of the data and all the transformations it undergoes. This allows us to understand, if data arrives incorrectly at a dashboard, at what point in the chain it became corrupted.

6.3.3 The use of data: the exploitation of value

This is the ultimate goal of DO: to ensure that data are used to generate public or business value, fostering a Data-Driven culture.

- **Promoting advanced analytics**: DO not only delivers data, but also enables the tools (AI, Machine Learning, Big Data) so that analysts can extract patterns and predictions.
- **Democratization of access**: Through Self-Service BI platforms, DO allows non-technical users to query and visualize data without constantly depending on the IT department.
- **Strategic use cases**: Identify high-impact areas where intensive data use can optimize processes. In a municipal setting, this could be the use of mobility data to optimize public transport routes.
- **Data literacy**: The DO leads internal training to help public employees understand how to read, work with, analyse, and communicate with data effectively.

Synergy between the three pillars

The effectiveness of the Data Office lies in the balance of these functions:

1) Without government oversight, the use of data would pose a legal and security risk.
2) Without quality, the use of data would lead to erroneous decisions based on false information.
3) Without use, government and quality would be bureaucratic exercises with no return on investment.

Table 7: Governance, quality and use of data: objectives and instruments

Pillar	Primary responsibility	Final objective
Governance	Regulations, roles and catalogues	Trust and control
Quality	Cleansing, lineage, and monitoring	Truthfulness and reliability
Use	Analytics, visualization and culture	Value and strategy

In conclusion, the Data Office acts as the centre of excellence that ensures the organization possesses not only data but also the reliable knowledge upon which to build the future.

7 Conclusions and recommendations for city managers

7.1 Key messages

The evolution towards truly smart cities depends not only on the incorporation of technology, but also on the ability to manage data as a strategic asset. Current urban transformation demands moving beyond traditional models based on isolated systems and towards interoperable ecosystems, governed and oriented towards generating public value.

The city platform constitutes the operational infrastructure that allows for the integration, standardization and use of urban information across all sectors. However, its true potential is realized when this platform connects to a Data Space, capable of facilitating the secure and sovereign exchange of information among government agencies, businesses, operators and citizens.

Data spaces are not merely technological repositories, but trusted environments where interoperability, governance, and data sovereignty enable the creation of new services, improve decision-making, and foster public-private collaboration. Their value lies in transforming fragmented data into shared intelligence.

In this process, the Data Office is positioned as the central element of the entire strategy. Its role is not limited to technical management; it also acts as a guarantor of the quality, ethics, security and

governance of information. The Data Office coordinates stakeholders, defines policies, promotes interoperability, and ensures that the city evolves from a siloed approach to a culture of shared data.

Furthermore, a city ontology is essential to ensure a shared interpretation of information. Without a shared semantic layer, technical interoperability loses much of its value. Modern governance requires not only connecting systems but also aligning meanings.

The effective integration between city platform, data space and Data Office allows progress towards more sustainable, resilient and efficient urban models, aligned with the objectives of ecological transition, climate neutrality, circular economy and improvement of the quality of life of citizens.

Ultimately, data should not be understood as a technological issue, but as a strategic urban infrastructure. Those administrations that manage it effectively will be better prepared to respond to current and future urban challenges.

7.2 First steps for cities

Integrating a city into an ecosystem of city platforms and data spaces should not be approached as a large, isolated technological project. It is a progressive process of organizational, operational and strategic transformation. Success depends less on deploying additional technology than on establishing clear objectives, governance arrangements and responsibilities, and demonstrating that better use of data generates measurable public value.

For cities beginning this process, the following sequence provides a practical roadmap. The steps are deliberately ordered so that the city first understands its starting point, then establishes strategy and governance, demonstrates value through manageable interventions, and only subsequently moves towards greater technical and organizational complexity.

7.2.1 Assess the current situation and institutional context

The starting point is to understand the city's existing data environment. This includes identifying what relevant data exists, where it is located, who produces and manages it, which systems depend on it, and what the principal barriers to access, quality and interoperability are. The assessment should identify information silos, duplicated datasets, gaps in quality and documentation, and dependencies on external organizations.

This assessment should also map institutional authority. In many cities, important datasets are controlled by utilities, concessionaires, regional or national authorities, transport operators or other organizations outside the direct control of the municipality. Understanding who has the authority to collect, access, publish and share each type of information is therefore a prerequisite for defining the technical architecture.

7.2.2 Define the vision, objectives and data strategy

Before deciding what technological infrastructure to build, the city should determine what it wants to achieve with its data. The strategy should be expressed in terms of urban outcomes: what problems should be addressed, what services should improve, what decisions should be better informed, and what public value should be generated.

These objectives may relate to mobility, energy efficiency, climate resilience, water management, public services, urban planning, economic development or citizen wellbeing. The important point is that technology and data infrastructure are treated as means to achieve these objectives rather than as objectives in themselves.

7.2.3 Establish the operating and governance framework

The city should then determine how responsibility for data will be organized. This means defining the functions of the Data Office, assigning responsibilities for data ownership and stewardship, establishing decision-making and accountability mechanisms, and determining how these functions will be resourced. Where a dedicated Data Office is not viable, its functions can be introduced progressively, assigned to existing structures or delivered through shared arrangements between municipalities.

At this stage, the city should also establish the basic governance framework: data classification and quality rules, access and usage policies, security and privacy requirements, ethical safeguards, and procedures for managing the participation of external actors. Governance should precede large-scale technical integration, since interoperability without agreed responsibilities and rules merely connects previously separate problems.

7.2.4 Establish a common basis for interoperability

Once responsibilities and governance rules are sufficiently clear, the city can progressively establish the semantic and technical foundations required for information exchange. This includes adopting common data models, ontologies, metadata conventions, APIs and open interoperability standards where appropriate.

The objective is not to standardize every municipal dataset before any action can begin. Rather, the city should establish a common framework that can initially support priority datasets and use cases and then expand incrementally. This reduces technological dependency and makes information increasingly understandable and reusable across departments, systems and external organizations.

7.2.5 Demonstrate value through an initial use case

Rather than attempting to integrate every municipal system at once, cities should begin with one or a small number of clearly defined use cases with visible and measurable outcomes. Appropriate starting points are those for which relevant data are reasonably accessible, institutional responsibilities are manageable, and benefits can be demonstrated within a relatively short period.

Examples may include reducing non-revenue water, optimizing energy consumption in public lighting, improving waste collection, supporting sustainable mobility or introducing predictive maintenance. The initial use case should be evaluated against explicit indicators so that the city can demonstrate not only technical feasibility but also operational, economic, environmental or social value.

Early results are particularly important where resources are constrained. A successful first deployment provides evidence for subsequent investment and can strengthen the business case for external funding. Where appropriate, investments can be framed in terms of climate resilience, sustainable infrastructure or improved public-service delivery rather than solely as expenditure on information technology.

7.2.6 Evaluate, refine and expand

The first implementation should be treated as a learning process. The city should evaluate what the use case revealed about data availability, quality, governance, interoperability, institutional coordination, skills and costs, and use these findings to refine its operating model.

Further use cases can then be added progressively, reusing the governance mechanisms, standards, infrastructure and organizational capabilities already established. In this way, the city platform develops incrementally around demonstrated needs rather than through a single comprehensive deployment whose benefits may only become visible after several years.

7.2.7 Progress towards external data spaces and collaborative ecosystems

Participation in sectoral, regional, national or cross-border data spaces should follow the establishment of sufficient internal governance and interoperability capacity. Before exchanging data externally, the city needs to know which data it can share, under what conditions, who is responsible for it and how usage rights and obligations will be enforced.

Participation should, therefore, expand progressively from internal coordination towards external collaboration with utilities, transport operators, businesses, research organizations, other public administrations and other data-space participants. The terms of participation – including access conditions, responsibilities, usage policies, incentives and dispute-resolution mechanisms – should be explicit.

7.2.8 Consolidate organizational capacity and a data-driven culture

The transition ultimately depends on people as much as on governance and technology. Public officials, technical staff and managers need the skills to understand data, interpret evidence, apply governance rules and incorporate data into operational and strategic decisions.

Consequently, training, knowledge sharing and cross-departmental collaboration should accompany the entire process rather than being treated as a final activity. The long-term objective is to make evidence-based decision-making and responsible data management part of normal municipal practice.

For cities with constrained financial, technical or institutional capacity, these steps should be understood as cumulative and scalable rather than as requirements for a large initial programme. A city does not need a complete platform, a fully staffed Data Office or comprehensive interoperability across every department before it can begin. It needs a clear understanding of its starting point, an agreed direction, minimum viable governance and a use case capable of demonstrating value.

The guiding principle is therefore simple: start with purpose, establish governance, demonstrate value, learn, and scale progressively. This approach reduces implementation risk, makes investment easier to justify and creates a more durable foundation for participation in wider urban data ecosystems.

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