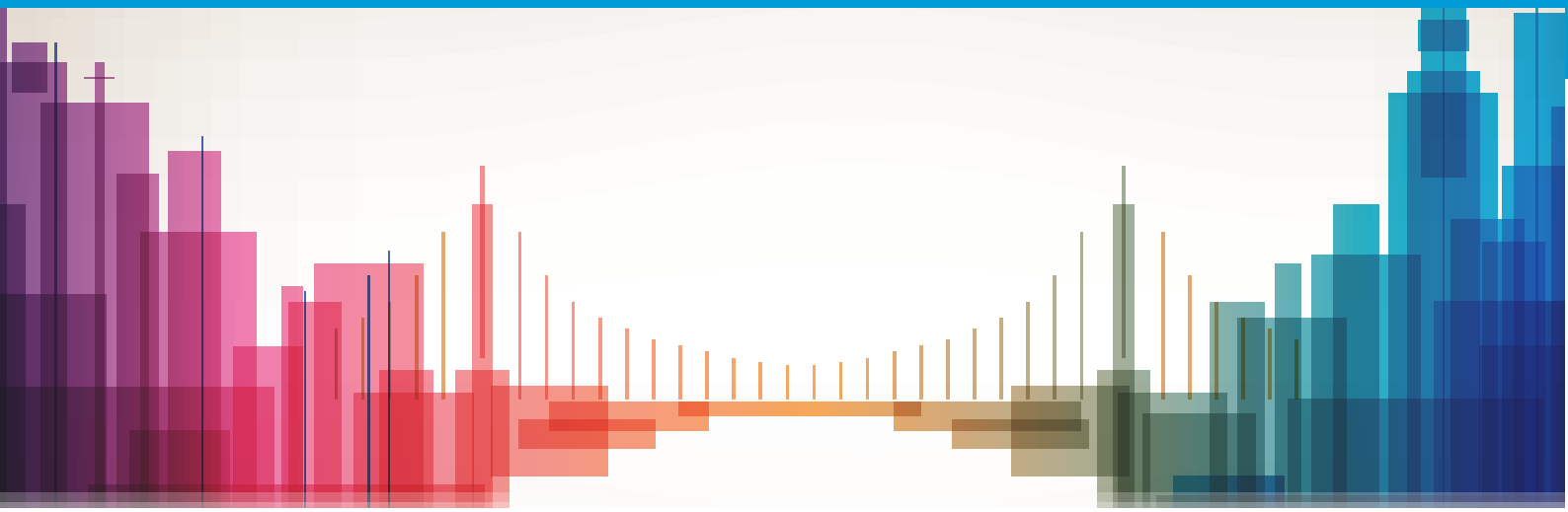
United 4 Smart Sustainable Cities

Reference framework for integrated management of an SSC

A U4SSC deliverable on City Platforms



Convention on Biological Diversity

United Nations ECLAC

Food and Agriculture Organization of the United Nations

UNIDO

ITU

UNDP

United Nations Economic Commission for Africa

UNECE

United Nations Educational, Scientific and Cultural Organization

UNEP

UNEP FINANCE INITIATIVE

United Nations Framework Convention on Climate Change

UN HABITAT FOR A BETTER URBAN FUTURE

United Nations Department of Economic and Social Affairs

UN OFFICE 4 PARTNERSHIPS

UNU EGOV

UNWTO World Tourism Organization

UN WOMEN

WORLD METEOROLOGICAL ORGANIZATION

United 4 Smart Sustainable Cities

Reference framework for integrated management of an SSC

A U4SSC deliverable on city platforms

Foreword

This publication was developed within the framework of the United for Smart Sustainable Cities (U4SSC) initiative.

Acknowledgments

The development of this deliverable was led and coordinated by Cristina Bueti (ITU) and Ramón Ferri (Former Smart City Officer of the Valencia City Council, current Director of Institutional Relations at SEGITTUR, Spain). The deliverable is based on the support and participation of the staff of the Smart City Office of the Valencia City Council, led by Pere Fuset, Delegate Councillor for Digital Agenda and Electronic Administration, Ernesto Faubel, Víctor Sancho, José Pinedo, Ángel Gómez and Javier Llavador, together with the work of several members of U4SSC who diligently contributed to the preparation of the report.

The Valencia City Council authors would like to express its sincere gratitude to the experts who have participated in the working group, particularly Hani Eskandar (ITU), Yolanda Martínez (ITU), Vikash Madduri (ITU) and Victoria Papp (ITU), for their input to the discussion, along with relevant feedback and reviews that contributed to the overall enhancement of this report.

The authors would like to give special thanks for the integration of visions, good practices and valuable tourism use cases showcasing the wide utility of smart tourism in a smart city environment to SEGITTUR (a state-owned company attached to the Spanish Secretary of State for Tourism in charge of the Smart Destination Project), led by its President Enrique Martínez, to the VP of the Smart Cities and Smart Tourism commission from AMETIC John Mora Williams, and to the vocal member of UNE Technical Committee for Standardization 178, Daniel Da Silva.

The authors wish to thank the U4SSC management team: Nasser Al Marzouqi (U4SSC Chairman), Katrina Naut, Abdurahman M. Al Hassan, Paolo Gemma, Tania Marcos and Giampiero Bambagioni (U4SSC Vice-Chairman) for their assistance and contributions.

The authors also extend their gratitude to the contributing organizations along with their representatives: Oliver Hillel from the Convention on Biological Diversity (CBD), Lucy Winchester and Vera Kiss from the Economic Commission for Latin America and the Caribbean (ECLAC), Simone Borelli from the Food and Agriculture Organization (FAO), Cristina Bueti (ITU), Deniz Susar from United Nations Department of Economic and Social Affairs (UNDESA), Iryna Usava from the United Nations Development Programme (UNDP), James Murombedzi from the United Nations Economic Commission for Africa (UNECA), Guilherme Canela from the Regional Bureau for Sciences in Latin America and the Caribbean of the United Nations Educational, Scientific and Cultural Organization (UNESCO), Martina Otto and Sharon Gil from United Nations Environment

Programme (UNEP), Matthew Ulterino from the United Nations Environment Programme Finance Initiative (UNEP-FI), Motsomi Maletjane from the United Nations Framework Convention for Climate Change (UNFCCC), Pontus Westerberg from the United Nations Human Settlements Programme (UN-Habitat), Gulnara Roll from the United Nations Economic Commission for Europe (UNECE), Katarina Barunica Spoljaric and Nicholas Dehod from the United Nations Industrial Development Organization (UNIDO), William Kennedy from the United Nations Office for Partnerships (UNOP), Naci Karkin from the United Nations University – Operating Unit on Policy-Driven Electronic Governance (UNU-EGOV), Sylvia Hordosch from the United Nations Entity for Gender Equality and the Empowerment of Women (UN-Women), Alexander Baklanov from the World Meteorological Organization (WMO) and Sandra Carvao from the World Tourism Organization (UNWTO).

Disclaimer

The opinions expressed in this publication are those of the authors and do not necessarily represent the views of their respective organizations or U4SSC members. In line with the U4SSC principles, this report does not promote the adoption and use of Smart City technology. It advocates for policies encouraging responsible use of ICTs that contribute to the economic, environmental, and social sustainability as well as the advancement of the 2030 Agenda for Sustainable Development. The study conducted in this report is based on extensive literature review and voluntary written contributions from stakeholders.

ISBN

978-92-61-37811-0

Contents

List of figures

Figures

List of tables

Tables

List of abbreviations

3G	Third generation of mobile phone technologies
3GPP	3rd Generation Partnership Project
4G	Fourth generation of mobile phone technologies
5G	Fifth generation of mobile phone technologies
AENOR	Spanish Association for Standardization
AI	Artificial Intelligence
API	Application Programming Interface
API REST	Protocol of data exchange and manipulation in Internet services
APN	Access Point Name, gateway between a mobile network and another computer network
AS NGN	Operator Application Servers
BHCA	Attempts of busy hour calls
BI	Business Intelligence
BIM	Building Information Modelling
BMS	Building Management System
BSI	British Standards Institution
CAPEX	Capital Expenditure
CBBs	Core Building Blocks
CEF	Connecting Europe Facility
CEP	Event Manager
CIO	Chief Information Officer
CIR	Caudal guaranteed average (Committed Information Rate)
CKAN	Portal Open Data (Comprehensive Knowledge Archive Network)
CMN	Corporate municipal network
COS	Class of Service
CP	City Platform
CSBBs	Common Solution Building Blocks
CSV	Comma separated value
DBA	Analytics Database
DF	Default Forwarding
DSL	Digital Subscriber Line
DWDM	Wavelength Division Multiplexing
EC	European Commission
EF	Expedited Forwarding
EIF	European Interoperability Framework
EIF-4SCC	European Interoperability Framework for Smart Cities/Communities
EIP-SCC	European Innovation Partnership on Smart Cities and Communities
EMT	Municipal Transport Company
ESB	Real-time data loading, Enterprise Serial Bus

(continued)

ETL	Information loading tools and integration with external systems (Extract, Transform and Load)
ETSI	European Standards Organization
EU	European Union
FG-SSC	Focus Group on Smart and Sustainable Cities
FIWARE	Open-Source Platform
FTP	File Transfer Protocol
FTTB	Fibre to the Building
FTTC	Fibre to the Curb
FTTH	Fibre to the Home
FTTx	Broadband access over optical Fibre that replaces all or part of the copper in the access loop
GDPR	General Data Protection Regulation
GIS	Geographic Information System
GovStack	GovStack is an application construction and cloud-hosting solution which is secure, fault tolerant and scalable with a readily programmed data infrastructure build that is regulation compliant
GPON	Gigabit Passive Optical Network
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
H2M	Human to Machine
Hadoop	Framework software that supports applications distributed under a free license
HDFS	Distributed file system that stores data on consumer equipment
HQ	High Quality
HTC	Human Type Communications
ICT	Information and Communication Technologies
ID	Digital Identity
IEC	International Electrotechnical Commission
IndEA	India Enterprise Architecture Framework
IoT	Internet of Things
IP	Internet Protocol
ISM	Industrial, Scientific, and Medical radio frequency
ISO	International Organization for Standardization
ITU-D	ITU Telecommunication Development Sector
ITU-T	ITU Telecommunication Standardization Sector
IUDX	Urban Data Exchange
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LDAP	Application-level protocol that allows access to an orderly and distributed directory service

(continued)

LoRaWAN	Specification for low-power, wide-area network
LPWAN	Low-Power Wide-Area Network
LTE	Standard for High-Speed Wireless Data Transmission Communications for Mobile Phones and Data Terminals (Long Term Evolution)
M2M	Interchanging information in the form of data between machines (Machine to Machine)
MGW	Media Gateway
MIMO	Multiple-Input and Multiple-Output
MongodB	Non-SQL database
MPLS	Multiprotocol Label Switching
MQTT	Message Queue Telemetry Transport
MTC	Data communication between devices that do not require human intervention (Machine-type Communication)
MVA	Minimum viable architecture (under IndEA Framework)
MySQL	Open-Source Database
NBIoT	Mobile network designed for IoT (Narrowband IoT)
NGN	Next Generation Network
NGSi	Next Generation Services Interface
NUIS	National Institute of Urban Affairs
OA&M	Operation, Administration and Maintenance
OneM2M	Standard of M2M
ONT	Optical Network Termination
OPEX	Operational expenditures
OTN	Optical Transport Network
PaaS	Virtualization. Platform as a Service
PLC	Power-Line Communication
PON	Passive Optical Networks
PPP	Public Private Partnership
PSTN	Public Switched Telephone Network
QoE	Quality of Experience
QoS	Quality of Service
RFID	Radio Frequency Identification
SCADA	Supervisory Control And Data Acquisition
SCC	Smart City & Community
SCP	Smart City Platform
SDGs	Sustainable Development Goals
SDK	Software Development Kit
SDO	Standards Developing Organization
SG20	SG20: Internet of things (IoT) and smart cities and communities (SC&C)
SIGFOX	Global cellular connectivity solution for the Internet of Things

(continued)

SLA	Service Level Agreement
SLC	Street Lamppost Controllers
SNMP	Standard monitoring protocol
SQL	Structured Query Language
SSC	Smart Sustainable City
STH	Short-term historical
U4SSC	United for Smart Sustainable Cities
UDP	Urban Data Platform
UDP	User Datagram Protocol
UN	United Nations
UNE	Spanish standardization Body
UNECE	United Nations Economic Commission for Europe
UNI	User Network Interface
UNWTO	World Tourism Organization, a UN Specialized Agency
VLAN	Virtual Local Area Network
VoIP	Voice over IP protocol
VPN	Virtual Private Network
VPN-IP	VPN commercial carrier service
WAN	Wide Area Network
WDM	Wavelength Division Multiplexing
Wi-Fi	Technology that enables wireless interconnection of electronic devices
WMO	World Meteorological Organization
WoG	Whole-of-Government
WPAN	Wireless Personal Area
WSN	Wireless Sensor Networks

Executive Summary

The United for Smart Sustainable Cities (U4SSC) initiative is a global platform dedicated to supporting cities in becoming smarter and more sustainable. The U4SSC is coordinated by the International Telecommunication Union (ITU), the United Nations Economic Commission for Europe (UNECE) and the United Nations Human Settlement Programme (UN-Habitat), with the support of 16 other UN bodies.

In recent years, Smart City initiatives have been based mainly on the application of information and communication technologies in the urban environment, allowing a substantial improvement in communication with citizens, better use of resources and a greater alignment of the services provided with the real needs of the community.

However, these initiatives have been managed, in many cases, in isolation and from different departments with the aim of automating internal processes or solving sectoral problems within their sphere of responsibility. This sectoral and uncoordinated approach does not consider synergies with other areas in the design of solutions, and can produce duplications, incompatibilities and inefficiencies that have a significant impact on their sustainability in the medium- to long-term.

The implementation of the UN Sustainable Development Goals (SDGs), especially SDG11, represents a unique opportunity for the digital transformation of cities from a global perspective, putting the citizen at the centre of its activity to improve the living conditions of residents, generate economic growth and embrace sustainability. This approach poses a challenge to municipal officials to identify what it means to be intelligent, what would be the different functions of the city, and what would be the way to solve the present and future problems they face to implement this paradigm.

The urban reality is complex and depends on multiple cultural, economic, geographical, and political factors. Not all approaches are equally relevant to a Smart and Sustainable City; for example, the perception of a Smart City in Europe could be one that focuses on reducing emissions. In America, advanced transport infrastructure may be a priority.

The only use of technology is insufficient to achieve this urban digital transformation if it is not accompanied by unified management that aligns objectives, resources and provides cities with a solid basis to incorporate elements that support the transition of their generally fragmented operations towards integrated management, using data as the main asset for the improvement of processes, internal efficiency, the conservation of the environment and to respond to citizens' demand for quality services.

This document "*Reference framework for an integrated management of a smart sustainable city*" is part of the results of the Thematic Group of City Platforms[1] promoted by U4SSC and has been designed as a complement to the reports published of this Thematic Group: "*IT Solutions for integrated cities management & Use Cases*", "*Smart Public Health Emergency Management*" , "*Smart*

City Platforms-Transitioning to a new architecture", "Tourism, Health and Resilience Management from the perspective of a Smart City Platform"

To help cities currently committed to the Smart and Sustainable Cities strategy promoted by U4SSC, this document delves into different aspects related to the description of a reference framework for integrated city management. The first chapter "*Current context of cities*" describes the current challenges, the digital government of the city based on values, the regulatory framework, and the enabling elements for an intelligent ICT management.

In the chapter *"IT Government of a city",* a conceptual vision of the SSC is described, what are the main levers of transformation in strategic management, as well as the organization and functions of a possible department of a transversal nature that leads the execution of the strategy and the future vision in the medium to long term.

Because the reality of cities is complex and heterogeneous in terms of their own urban nature, degree of technological development and available resources, the following chapters describe a technological architecture objective, "*Urban digital reference architecture"* that encompasses the connectivity and technological systems of an SSC, and that can serve as a model for the technological evolution of the city.

In a sustainable and intelligent urban ecosystem, the convergent communications network must be able to support the deployment of thousands of heterogeneous devices (Internet of Things, or IoT) to provide intelligence to physical infrastructures, ensuring the quality and availability of the underlying services. This aspect is relevant because a large part of the success of this transformation depends on adequate connectivity and how these devices are deployed in the city area.

Moreover, urban platforms – understood as the set of collaborative information systems – provide cities with a solid technological base to incorporate, in an organized manner, the necessary elements for their digital transformation.

The chapter "*Business and application components*" deals with different initiatives for the development of innovative, efficient, secure, and economical digital services. Different initiatives such as GovStack, allow these objectives to be achieved with re-usable functional blocks, thus achieving economies of scale, avoiding duplication of investments, and allowing municipal managers to focus on providing innovative services and solutions to citizens, companies, and the public sector.

Lastly, the chapter "A Path to City Transformation" provides a set of recommendations based on authors experience in the strategic, technological and management areas, which can serve as an introductory guide to city managers and other stakeholders related with the process of transformation towards a smart and sustainable city.

1 Introduction

The purpose of the deliverable is to help cities identify the strategic, operational and connectivity needs that a Smart Sustainable City's integrated management can meet.

- Identify the basic principles of action, the critical success factors and the associated underlying risks.
- Describe a high-level methodology that facilitates implementing an urban digital infrastructure based on standard and technical requirements independent of the political and economic context.
- Identify the functional blocks (Building Blocks) proposed by the GovStack Initiative and their alignment with the standards on interoperability and architectures of ITU-T Study Group 20.
- Define the key elements and the path towards the transformation of a smart and sustainable city.

As stated in the scope of the document, the paper's target audience is focused on city technicians so that they have a guide that allows them to identify the needs that their municipalities may have.

From a municipal perspective, we try to solve the following questions:

- How can cities assess their starting point and determine their digital transformation needs?
- Citizens demand safety, security, affordable and good quality services, clean air, convenient transport... What enabling technological capabilities are necessary to meet citizens' needs and aspirations?
- Which monitoring strategy can we follow through the city indicators? What are the primary standards, and how are they chosen?
- What regulatory requirements do cities need to comply with, when implementing ICT solutions?

The role of today's cities has been studied for years as part of the disciplines of urbanism, sociology, the environment, information and communication technologies, among others. Currently, cities have been showing an evident willingness to participate in international relations, actively proposing local solutions to problems with an increasingly global dimension.

Cities have the ability and autonomy to mobilize resources that allow them to achieve their goals and can exert influence over other actors in the system.

Problems such as climate change, energy, food security, pandemics, poverty and pollution can hardly be solved by the national governments alone. It is precisely within the area of sustainability, and in the relationship and proximity with citizens where cities play a greater role.

Participation in transnational municipal networks such as the United for Smart Sustainable Cities (U4SSC) has become an opportunity to make local policies visible at the international level, and to contribute to the dissemination of good practices or the exchange of ideas, knowledge and experience, which contributes to invigorating relations between cities.

The current governance of cities, e.g., political and social neighbourhood, necessarily involves making appropriate decisions, or at least decisions aligned as much as possible with citizens' demands, without giving up compliance with internationally established sustainability standards. The idea of having adequate data and information management frameworks is key in the good governance of cities and as a reinforcement in the motivation of the discretionary decisions that define:

- Urban planning and changes in urban design.
- Citizen participation.
- The reduction of the digital gap.
- The integration of municipal services with other entities, whether regional or national.
- The exploitation of public data for use by the business ecosystem.

Nowadays, any public entity should define itself and focus on providing an efficient and effective service to citizens based on at least two essential principles: intelligence & smartness, and sustainability. A Smart City is not only a sensorized city, but also a city that obtains value from the data it generates and acts accordingly considering the opinion of citizens. A Smart City is a city that learns to adapt to its circumstances and its environment and has the capacity to transform all sectors of the population.

A Smart City is a city whose inhabitants have opportunities and safe spaces for learning and sharing; a place to experiment in collaborative processes that expand creativity and collective wisdom for the design and implementation of common projects. A city with attentive citizens connected to its purpose, with businesses that are aware of their social responsibility; knowledge entities at the service of societal challenges, and an open and enterprising government that assumes its leadership responsibilities in the face of challenges. As defined in Recommendation ITU-T Y.4900:

> *"A Smart Sustainable City is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, the efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects".*

These notes on global management, the use of information and communication technologies to improve citizens' quality of life, and reinforcement through them converge in the conceptual

understanding of Smart Cities. The key principles are transparency, participation, and accountability of sustainable development at an economic, social and environmental level.

The Smart City must be a city at the service of its citizens and must respect basic citizenship rights. Its institutional organization (political-administrative) will have to embrace the principles of efficiency, transparency, cooperation and responsibility. All this, together with the new forms of management and governance, is undoubtedly not yet precisely defined and has not yet, generally, been implemented but must change our perception of public action.

Through their different indicators and metrics, Smart Cities' sustainability and efficiency objectives can only be achieved through the analysis and exploitation of the information generated as a result of the correct management of city platforms and the applications derived from it.

The use of the Platform and other enabling elements – specifically of the data associated with the provision and use of municipal services, municipally-owned spaces, and infrastructures that are now generated by Big Data, cloud computing and the Internet of Things (IoT) – represents an improvement in the provision and exploitation of internal municipal services by public officials and by citizens, and an improvement in the use of municipal services. In recent times, we have witnessed a certain institutional, functional and operational evolution, but also organic and structural evolution of social needs. This has occurred fundamentally at the local level of government, despite the restrictive competence reforms that have taken place in some countries, and countries and is clearly based on the principles of superior control and balance and economic-financial sustainability.

The modern notion of citizenship no longer focuses exclusively on the relationship between a person and a territory but instead on the functional exercise of a series of inalienable rights and participation in democratic life.

For good local administration and governance to exist, there must be a proper technological structure where services for the benefit of citizens can be audited and managed effectively and efficiently.

Furthermore, it is essential for smart cities to understand their roles in the different economic activities that take place on their territory. Such is the case for sectors such as tourism, which, when considered as a vertical of the smart and sustainable city framework, not only supports its philosophy aimed at cost efficiencies and residents' quality of life improvement, but also represents a new way to generate income and job opportunities that translate into prosperity for the local citizens. Therefore, it is indispensable for cities to consider tourism as part of their smart and sustainable city strategy since, in most cases, it constitutes a reality that coexists with the resident life, thus requiring appropriate planning.

All in all, the smart tourism inclusion in the present framework, will contribute to the management of conflicts derived from the shared use of spaces and services between residents and tourists. It will also ease the path for public administrations towards the provision of vital information, transform the tourism offer towards competitive models, and finally, make it possible to provide tailored

experiences. The integration of smart tourism into the existing framework has the potential to address conflicts between residents and tourists, improve the quality of services offered to tourists, and provide better information to the public. The implementation of enabling technologies can also help to transform the tourism industry and make it more competitive by providing tailored services that meet the expectations of modern travelers. This can lead to an overall improvement in the tourist experience and help to ensure the long-term sustainability of the industry.

Smart tourism and sustainable cities are two important concepts that are closely related to one another. Smart tourism refers to the use of advanced technologies and data analysis to enhance the tourism experience and create more efficient and sustainable tourism systems. On the other hand, sustainable cities are those that have been designed and developed in a way that minimizes their environmental impact and promotes social and economic well-being.

2 Current context of cities

Cities face particular challenges, depending on the geographic and demographic context; their needs vary, and may be completely different from one another.

We focus this study on cities. We describe the services that must be provided and the actors' point of view.

We focus on the digital transformation strategy of cities, trying to focus on everyday needs regardless of size and location.

The current situation, derived from the pandemic, has been a great challenge for all cities, especially in developing countries. The technological needs, the standardisation, and the use of the data are the challenges they face. We pose the following questions:

- Is a Smart City also a sustainable city?
- How can the SDGs contribute to the development of cities? or how can cities' development be inspired by SDGs?
- How does SDG 11, Sustainable Cities and Communities, apply in the development of cities?
- What guidance can we use to develop an SDG action plan?
- With which regulations must cities comply, and what standards must they meet to make an innovative and sustainable city?
- How can the economy of data and data as a good practice in terms of transparency improve the economic, business, and industrial fabric and, in turn, be a tool for transparency in cities?
- Does the technology used affect the privacy of citizens? What have the general data protection regulations and other analogous regulations meant for privacy and data management?
- What are the main barriers to the implementation of an urban digital infrastructure?

Since it was first incorporated in the early 1990s, the "Smart City" concept has moved on from using information technology to help address cities' needs, including a focus on sustainability, along with resilience, inclusion, and citizen engagement and participation.

This transition has occurred mainly due to the rise of new digital technologies such as Artificial Intelligence, blockchain, cloud computing, and the Internet of Things. Smart embedded devices can provide city managers with real-time spatial, economic and environmental data for improved and

agile decision making. The city's data platform infrastructure is a key element of this transformation, ensuring seamless communication between heterogeneous systems and technologies.

The Telecommunication Standardization Sector (ITU) and its members within ITU-T Study Group 20, which is dedicated to IoT, smart cities and communities, have been developing international standards that establish technical criteria, processes, and practices to enable the coordinated development of IoT technologies for smart sustainable cities. Most recently, the study group has been working on topics including AI, blockchain, machine-to-machine communication and Big Data aspects of IoT.

ITU-T Study Group 20 is developing standards on digital inclusion in smart cities, next-generation urban assessments, maturity model for digital supply chains, digital transformation in smart cities, crowdsourcing for urban infrastructure monitoring, smart fire protection, smart buildings, data middle-platform in IoT, among others.

The city's competitiveness in the above definition refers to "policies, institutions, strategies, processes, and innovation that determine the sustainable productivity of the city."

Smart and Sustainable Cities successfully adopt advanced digital technologies and ICTs to improve their performance according to the Sustainable Development Goals (SDGs) and urban growth and technological proliferation requirements. By doing so strategically, they harness the tremendous potential to improve urban operations, functions, services, designs, strategies, and policies for the benefit of citizens and the environment.

Smart and Sustainable Cities do so, in part, by combining the role of ICT as a platform for aggregating information and data (City Platform) with traditional infrastructures. ICTs in Smart and Sustainable Cities provide valuable information on consuming resources and services.

ICT-based urban services in Smart and Sustainable Cities provide, among others, benefits related to:

- Improving energy and climate efficiency.
- Operation and transparency of urban infrastructure.
- Urban mobility and resilience.
- The efficiency of water distribution systems.
- Waste management.
- Security.
- Other services.

Furthermore, ICTs must establish defined urban functions in Smart and Sustainable Cities and help foster participation during the city design and planning process among citizens, governments, businesses, and other stakeholders. This engagement is expected to facilitate participation and the sharing of knowledge for urban governance, which is essential to keep the city's future economic, social and environmental development in line with a credible smart sustainable vision.

In this same way, some urban spaces are subject, to a greater or lesser degree, to modern global phenomena such as tourism, an activity which nowadays involves a massive yearly movement of nearly 900 million tourists according to 2022 data from UNWTO. The reception of such a volume of tourists is a reality that comes with unavoidable impacts that must be faced when defining the smart and sustainable city strategy, due to the fact that these spaces constitute one of the main tourist consumption scenarios.

Even with this definition and understanding of a smart sustainable city, its manifestation varies by city, country, and region, depending on the city's level of development, cultural attitudes towards change, financial resources, technical landscape and capabilities, and general aspirations. A Smart and Sustainable city in Africa would be unique for that country and the context of the region, compared with its counterpart in the context of Latin America, South Asia or North America. ITU-T is helping to build Smart Cities in many different forms:

- Technical standards to harmonize and protect key investments in ICT infrastructure.
- U4SSC Initiative[2].
- Toolkit on Digital Transformation for People-Oriented Cities and Communities[2].

2.1 Challenges facing Smart and Sustainable Cities

Intelligent infrastructure adoption is slow and needs to be managed carefully fundamentally due to high investments and long amortization periods. There are various levels of adoption of this type of technology depending on location, the capacity of local leaders and officials, the strength of the local market, and the type of technology being implemented.

There are some barriers to smart infrastructure adoption such as:

- Cross-cutting nature of smart infrastructures. The deployment of an intelligent infrastructure can constitute a solid base for the development of economies of scale that would benefit different departments and stakeholders, promoting the economic development of the community: however, it increases complexity since it requires internal coordination and shared costs between different areas.

- The Smart City market is still too solution-centric. The created solutions must be more focused on the needs of the city and citizens. By addressing this mismatch, we can better incentivize suppliers to provide what is needed and encourage greater diversity in the market. Cities can accelerate this by defining their "use cases": descriptions of how and why they see a value or "use" of smart infrastructure. These use cases will be familiar to many cities; sharing experiences can speed up this process.
- Investment is a challenge: Investment in infrastructure is irregular (discontinuous) and often focuses on specific solutions, not on the city's bottom line. There is a lack of proven business models that provide security to private investors. It is not easy to demonstrate a return on investment for technology that is often less than five years old.
- Interaction with private smart infrastructure is limited: While city authorities will be responsible for implementing the most visible smart infrastructure on the street, much of the smart infrastructure in a city will be privately owned. Depending on how these assets are managed, the municipality may have little control or oversight of this technology and its uses.
- Interoperability between different systems: A barrier to achieving the full impact of massive data use and a genuinely interconnected city is the challenge of interoperability between the various systems and platforms within that city. This challenge is amplified in large, fragmented cities with multiple layers of public sector agencies.
- Public perception can be harmful: A good example is the conspiracy theory that "5G causes COVID-19"; but even at the lower end of the spectrum, many people associate smart technology with a surveillance culture and an invasion of privacy. More open and honest discussions between municipalities and citizens are the key to generating public support to help the public understand the value of services, improvements, and benefits that smart infrastructure can provide.
- Ethics and Transparency: To ensure that the technology that cities implement does not affect people's privacy or cause further inequalities in society, we must ensure that technology is taken care of ethically and provides a transparent and accountable smart infrastructure. This is particularly important when it comes to data collection and use. Strong governance and clear guidelines are needed to address these challenges at the start-up stage.
- While most officers know what cybersecurity is and some of the problems that its lack can cause, their understanding of how to approach cybersecurity when putting an intelligent infrastructure up and running in a city is still low. Knowledge is often found solely in teams or individuals. The government's orientation in this area improves, but it remains complex. A more targeted approach to this challenge is needed, including cybersecurity principles established by national governments and the use of pre-verification at the procurement stage.

2.2 Governance and Smart Cities

Smart cities demand continuous adaptation and local innovation governance, with new modern organizational and management structures, and new decision-making models based on openness, transparency, control, and effective accountability. It can only be achieved by providing an effective increase in the efficiency of public services, which will improve people's quality of life, and the optimum use of available resources without prejudice to the urban environment.

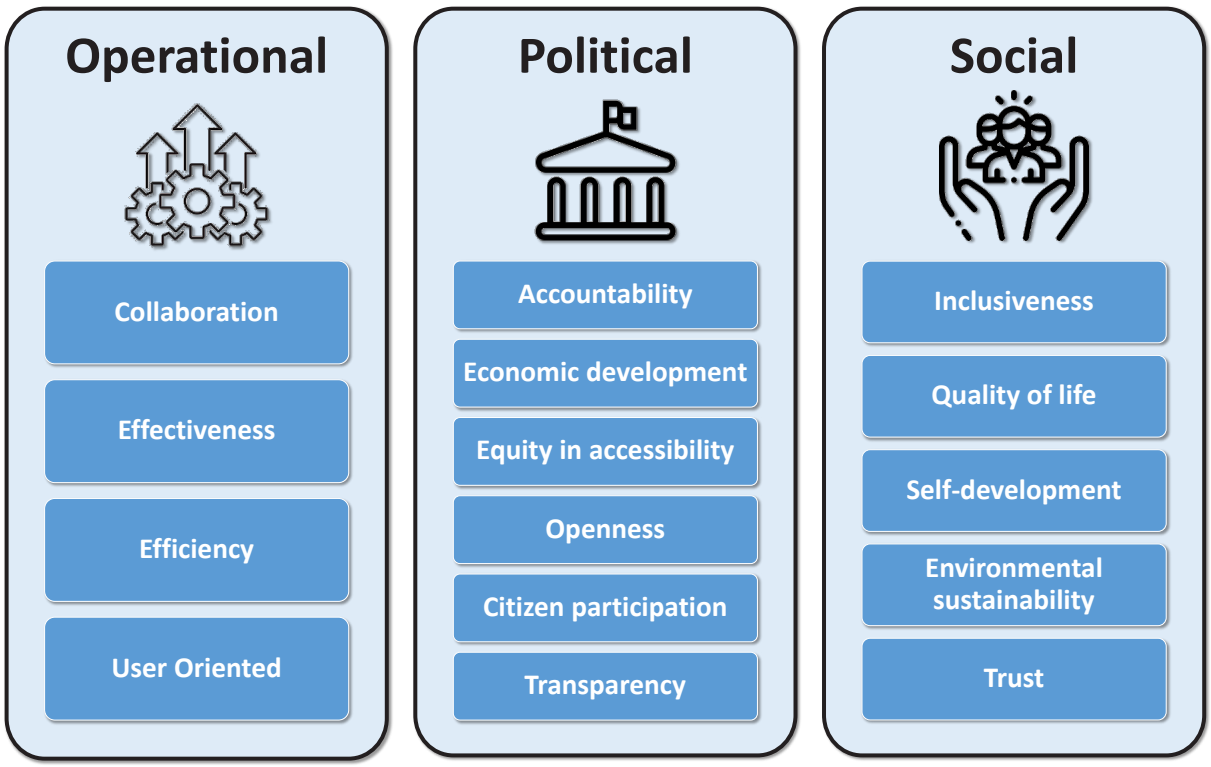
Actual participatory governance and sustainable intelligence in urban management change the very basal conceptions of its object and mission. The city is an articulated "system" or "network" of attention, regulation, provision of services, and the public service as a cooperative, open, and responsible action. And all this in an environment that is globally sustainable and technically advanced.

The open and relational Administration can "act" through the authentic articulation of interests in presence but from a necessary and adapted regulatory framework of guarantee. This integrated, global, and cooperative management of public interests (objectives) is presented, therefore, as a "process" in the improvement (in quality, efficiency, and usefulness) of the ways of acting and the temporary innovation of the same, a process (of constant improvement) of institutionalized and material nature.

In these objectives, the use of modern information, communication and interrelation technologies is presented as inescapable from the very framework of interoperability between the different urban subsystems. The digitalisation and virtualisation of public administrative action must pursue not only "the end of paper" but the authentic accessibility, knowledge and participation of citizens in it, with actions that solve problems and anticipate needs, so generating public value.

Public value could be categorized according to three categories of operational value, political value, and social value (see Figure 1). This framework is largely drawn from Chu and Tseng's (2018)[3] "Open Data in Support of E-governance Evaluation: A Public Value Framework" and has been supplemented with additional values from research as Osborne, S. P., Nasi, G., & Powell, M. (2021).[4]

Figure 1: Public Value Categories, Source: State of the Art Report, 2021[5]



The technological revolution applied to the administrative action of provision, service, and planning of the city can entail risks such as:

- Excessive automation and rigidity of procedures.
- Accessibility to sensitive data.
- Untrustworthy or malicious use of Artificial Intelligence applications.
- Cybersecurity on deployed devices.
- Difficulty of use for people with little digital training (social exclusion).

Efficiency, therefore, cannot end spontaneity, sociability and realism, much less undermine citizens' freedom of decision. The participatory governance of Smart Cities must seek a balance between these new requirements for openness and open data, the sustainable management of economic activity, and intercommunication with citizens in real-time, bridging the digital divide in citizen participation, avoiding vulnerability due to gender, age or disability.

2.3 Contribution to the Sustainable Development Goals

Material and immaterial resources are, in general, limited and, therefore, often configured for a stable environment. Any major crisis can affect multiple areas of the city and even different public

and private institutions. In this case, the provision or improvement of public services, especially to the vulnerable population, is the main objective of the effort of Public Administrations. Information management, available resources, and interoperability are key aspects in this section.

Since 2015, the United Nations' 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) have driven and inspired governments and other stakeholders to take transformative action, individually and collectively, for people, the planet, and for prosperity.

Goal 11 aims to *"Make cities and human settlements inclusive, safe, resilient and sustainable for cities and communities."* To meet the targets stipulated in this SDG 11, it is necessary to:

- Actively take an interest in the governance and management of the city.
- Identify what works and what does not.
- Develop a vision for buildings, streets and neighborhoods, and then act on that vision.

Development related to job creation, health, safety and security, mobility, environmental quality, shared public spaces, and the well-being of citizens are interrelated. In that sense, an efficient, holistic management approach to creating a vision to implement and improve action plans with relevant KPIs is an efficient technique to meet objectives and improve the overall quality of life.

Figure 2: SDG 11 - Sustainable Cities and Communities

ITU plays an active role in promoting and achieving the Sustainable Development Goals (SDGs) through ICTs.[6]

ITU addresses Goal 7, Affordable and clean energy; Goal 12, Responsible production and consumption; and Goal 13, Climate action through its climate programme, which devotes its efforts

to guiding the cities, the ICT sector and academia in climate change adaptation and mitigation, improving energy efficiency, reducing greenhouse gas emissions and using environmentally sustainable methods for e-waste management. Through the United for Smart Sustainable Cities (U4SSC) initiative, ITU is also committed to achieving Goal 11, Sustainable cities and communities.

The World Meteorological Organization (WMO) emerges as a fundamental stakeholder, assuming a leading role in developing and implementing Integrated Urban Services. Given its vast expertise and global influence, the WMO is uniquely positioned to spearhead this comprehensive approach to tackling urban challenges. The organization's plans to educate and train meteorologists in Integrated Urban Services methods represent a critical step in this direction.

Moreover, the WMO's commitment to extending existing services to a broad range of urban users shows its dedication to the cause. By facilitating collaborations and consultations among various experts and practitioners, the WMO plays a crucial role in defining user needs and ensuring that no single organization unilaterally decides them.

The WMO also recognizes the importance of integration at the modelling level, demonstrating this approach's efficacy in multi-hazard early warning systems. It is championing scientific advancements towards comprehensive Earth systems modelling and forecasting capacity at more minor, urban scales and over sub-seasonal and seasonal timescales.

Furthermore, the WMO encourages long-term decision-making in urban design, planning, sustainability, and emission reduction, all contributing to urban resilience in the face of climate change. With its broad perspective and deep understanding of Earth's complex systems, the WMO is equipped to guide this journey towards resilience, ensuring that Integrated Urban Services genuinely cater to urban environments' diverse and complex needs[7].

In this context, a thorough review of the state-of-the-art data infrastructures, including earth observations and social media data, becomes essential. These data resources provide invaluable insights into urban climate challenges, and there is a substantial opportunity to integrate these assets better to enhance our understanding and response to climate change in cities and urban areas.

Firstly, mainstreaming data collection could serve as a pathway to expand our knowledge of global urban areas. Consistent and comprehensive data collection across diverse geographical locations and socio-economic contexts can help capture a complete picture of urban climate challenges. By incorporating these data sets into climate science research and urban policy development, we can enrich our understanding of urban climate issues and devise targeted practical solutions.

Secondly, amplifying Big Data usage is another avenue that holds immense promise. The vast amounts of data generated through earth observations, social media platforms, and other digital footprints present a rich resource to be harnessed. We can use Big Data analytics to extract meaningful insights about urban climate patterns, people's behaviours and responses to environmental

changes, and the efficacy of implemented climate solutions. This approach can facilitate more precise and efficient decision-making, ensuring that real-time data inform interventions and are adaptive to rapidly changing urban landscapes.

Thirdly, taking further advantage of computational methods to analyze qualitative data could offer fresh perspectives. Techniques such as natural language processing and machine learning can process large quantities of qualitative data, bringing a nuanced understanding of public perceptions, attitudes, and experiences regarding urban climate change. This, in turn, can inform more empathetic and inclusive climate policies.

Ultimately, these data-based approaches can drive the upscaling of urban climate solutions, enabling change at a global scale. By harnessing the power of data, we can amplify the impact of urban climate interventions, fostering resilient urban ecosystems that can stand up to the challenges posed by climate change. The World Meteorological Organization's leadership in Integrated Urban Services is crucial in promoting these data-oriented strategies, thus accelerating global urban resilience[8].

SDG 11 is expected to lay the foundation for urban planning techniques and policies for the future. For the practical implementation of sustainability policies related to SDG 11, these policies should be implemented directly through urban planning interventions. These interventions are expected to transform the intangibility of policies into physical actions. These executions will have the help of ICT technology to introduce intelligence in these sustainable urban planning interventions, especially for the evaluation of the implementation procedure.[9]

The ITU Secretariat, the Council and members of the Plenipotentiary Conference worked on drafting this new Strategic Plan with clear links to the Sustainable Development Goals (SDGs) and a vision to impact the achievement of the SDGs. It includes an entire section called “Linkages to the Sustainable Development Goals”; which highlights the SDG Goals most relevant to ITU:[10] SDG 9 (Industry, Innovation, and Infrastructure) and Target 9.c; SDG17 (Partnership for the Goals) as a means of implementation; and SDG 4 (the Education goal).

In addition, the revised Resolution 200 entitled “Connecting the 2030 Agenda for Global Telecommunications from Information and Communication Technology, including Broadband, for Sustainable Development” shows a strong commitment of cities to the Goals in the new EP and closely aligns the strategic framework with the SDGs and their timetable.

2.4 Smart Cities and Crisis Management

COVID-19 shocked cities around the world, revealing vulnerabilities in many areas of urban life. Most of the cities experienced serious problems for a long time that affected major segments of the population, and the operation of municipal services. Planning played a critical role in efficiently responding to this crisis and enabling rapid functional recovery in the post-pandemic era. Cities that have implemented digitization initiatives and programmes are likely to have a greater capacity

to react appropriately. Specifically, digitized cities could ensure the well-being of their residents and maintain the continuity of urban functions.

Technology has increased participation and social connection, improved physical and mental health, and maintained the functionality of educational and economic systems. These have been achieved through various solutions and technologies such as social media, remote assistance (telehealth, teleworking), and IoT sensors & monitoring.

Improving urban resilience in Smart Cities implies the analysis of the role of technology in crisis management to understand what policy changes they need to implement to respond successfully to these challenges. Lessons learned from the COVID-19 pandemic show how smart city solutions and technologies can enable cities to better prepare for and respond to future similar disasters.[11]

City Applications must comply with Data Protection Regulations fully. In some cases, if necessary, they must be installed voluntarily, approved by the authorities, and dismantled once the crisis is over. They must exploit the latest solutions to improve privacy and interoperability. In addition, apps should rely on anonymous data so that they can alert people who, for example, might have been in close proximity with an infected person, without revealing the identity of the latter.

2.5 The digital transformation of cities as a basic piece in innovation

Smart City transformation has become clearer than ever.[12] The successful reinvention of our cities requires the adoption of a human-centred design approach. This focuses on harnessing the collective intelligence of communities to understand the human experience from the diverse perspectives of the people who live, work, learn and play in cities every day. This approach has even greater value as we are seeing a greater focus on the role of local neighbourhoods in strengthening community resilience.

The improvement of the municipal organization, at the organic, functional and resource level, as well as the means of management and preparation of services to the citizen implies not only the electronic collection of data and information and their proper treatment but also their practical use as an objective parameter for decision-making. This entails the possibility of offering citizens access to certain municipal information, "open data". The Smart City model is no longer a model of public rationalization of power: horizontal coexistence of agents or subjects (of transformation of the city) but makes the citizen an essential protagonist and receiver of all the actions developed in their natural habitat and a fundamental pillar of the digital transformation of this environment.

The most relevant feature of Smart and Sustainable Cities is the massive and growing use of information and communication technologies in city planning and management tasks to facilitate efficient, inclusive and integrated urban development. ICTs are the central element of this new paradigm that provide real-time information with which to evaluate the effectiveness, efficiency, and sustainability of public services through commonly accepted KPI's based on international

recommendations, such ITU-T Y.4903: "Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals."[13]

In this respect, adequate and rational management of the data obtained (in a massive way) by the local administration (Big Data), which becomes a "data administration", is also required. The principle of necessary transparency in management requires not only knowledge but also adequate understanding and, above all, openness to society of decision-making processes (based on the data and indicators obtained, where appropriate).

The value of the data generated by citizens through their devices, personal and professional, as well as by the multiple sensor networks deployed in the city by the Public Administrations is unquestionable:

- Shared spaces such as streets, equipment, infrastructure, street furniture, etc.
- For companies and citizens in particular spaces.
- Private, work places, leisure, etc.

Perhaps the most relevant note today of all smart services, from a smartphone to a Smart City, is precisely its technological capacity to capture or obtain data, analyse and transmit them, managing to provide "valuable information."

In this sense, to obtain and manage/treat (and its valorisation) of the data, it is necessary to add its interoperability. Without this – that is, without the interconnection of systems, applications and platforms for the management of data, documents and procedures – it does not seem possible to implement e-Administration projects or other derivatives such as the implementation and maintenance of sustainable and Smart City platforms.

From this point of view, and fundamentally to guarantee the privacy of specific data (subject to constant interconnection and re-use), it is necessary to properly determine the ownership of the information collected or transmitted to the Administration through the different services and applications put to the benefit of the Smart City. Generic data can be obtained, as can precise information about certain people, even from their behaviour. Consequently, the processing of these data must comply with the relevant regulations on the protection of personal data to ensure that their processing complies with strict parameters of responsible and adequate management.

ICTs cannot be an end in themselves, despite their significance, nor can data, without something more, be used to "improve" the city. This improvement goes through adequate and transparent management and their use as motivational criteria in the City Councils' final decision-making (complex). It would, in short, be to modulate the subjective (last) judgment of the municipal decision-making body (in sensitive areas and with a confluence of actors and interests, e.g., in urban planning) through the "objectivity" of the information derived directly from the management data, turning intelligence into adequacy and sustainability into the final parameter of motivation.

From the organizational point of view, local ICT structures are imposed (support and centralized and external development) and, more specifically, for the obtaining, management, systematization and interpretation of the data obtained through the systems involved.

In this sense, it must be considered that data collection can be done unconsciously (for citizens) and anonymously or directly through their participation in the participatory processes established or promoted by the administration itself.

The responsible municipal organization (services, personnel, and specific data-management platforms) will necessarily be different, requiring in the first case – except in the cases of contracting – much greater technical specialisation, as well as guarantees, fundamentally in terms of data protection (principles of access to minimum data, protection by design of management and anonymization applications and segregation of data to guarantee their privacy).

Nevertheless, and aligned with the human-centred design approach, the smart and sustainable city strategy must expand this concept to users of the city in general, a broad category inside which tourists need to be considered, given that they too interact with the services articulating the urban space. In their inclusion, cities must set in motion participation mechanisms through which, after identifying the main tourism stakeholders, digitalization initiatives are designed collaboratively, in order to generate solutions fitting their realities, paying special attention to sensitive actors such as SMEs and residents.

Consequently, there are examples of departments or Specialized Areas of Innovation and Urban Digitalization, whose functions include those related to Intelligent Management Systems, the digitisation of services or the incorporation into large municipal networks of knowledge and technologies, or of a more generic nature, as well as Open Data portals, whose objectives include transparency, the re-use of public information, the generation and incentive of economies and the promotion of new innovative services.

2.6 Strategic planning

The first characteristic note of the governance models of Smart Cities could easily be the need for a strategic vision/planning of the city and its future, and its necessary implementation through objectives and measures of practical innovation (integrated strategies of action that have to start, precisely, from the global perception of the state of the city previously obtained) with the central objective of achieving more advanced and efficient management of municipal services.

The Smart City cannot result from improvisation or government changes at the local level. A preliminary design and strategy are imposed, and in the medium to long term, of its evolution, growth and transformation obtained through processes of broad citizen participation, and with clear and affordable objectives.

The deployment of intelligent networks and infrastructures, the high investment cost, the associated environmental protection measures, and so on, require their insertion or, at least, the prior approval

of adequate strategic planning, of the costs and benefits, of the objectives to be achieved and of the actions to be implemented for it. This prior strategic planning should be coordinated with the rest of the planning instruments that impact the territory and adopt global and holistic approaches to achieve an intelligent urban environment. It is not enough to achieve optimal values in some indicators independently; starting from the systemic and reticular vision of the city, it is necessary to programme and execute, in a transversal and general way, the objectives to be achieved so that global and tendentially compensable results are obtained.

There is a double participation: users (holders of the ultimate public authority and recipients in the capacity of the services); and external providers, where appropriate. The adequacy and efficiency of the model – in organizational and operational headquarters later – would require the municipal administration to assess the different forms, ways properly, and times of public participation in planning procedures, as well as in contracting procedures (in the case of indirect or concessional management). If the companies in charge of urban services incorporate technological actions in the city, this would allow citizens to interact, in a simple and accessible way, through their mobile terminals with the system, thus participating in public affairs.

The management and/or provision of public services in this context – and from these parameters of innovation, excellence, and continuous improvement – clearly require new forms of organization of the responsible public administrations (participatory relational governance). It is, therefore, a question of planning, innovating in management, and through it, achieving better public services and the best possible quality of life for the benefit of all citizens.

One of the significant challenges in this regard is the correct legal-public organization of the "Internet of Things," whose systems allow the continuous acquisition of data by sensors installed in the city, their local storage or the cloud and the delivery (sometimes automated and in real-time) of orders to devices that interact with reality itself.

The Internet ceases to be just a virtual network of networks for information and communication and the exchange and creation of knowledge, to become an actual "*vital area*". Pairing (or interaction) of devices and data with a set of physical infrastructures of the city and its services can logically reduce costs of these and, at the same time, improve the overall sustainability of the system.

The use of these systems also requires adequate infrastructures for the storage and analysis of a growing volume of contextual information produced, sometimes in real time. In this dynamic environment, different solutions have been proposed such as WEB 3.0, or Blockchain, a technology capable of supporting decentralized and distributed databases with encrypted documentation and secure collaborative management.

It is also necessary to rethink the legal framework and the organization/administrative activity of using Artificial Intelligence systems in the provision of certain services or utilities to citizens. Likewise, there should be a rethink of the set of predictive analytics systems that can be applied to administrative activity, still very weakly intuited in the basic regulations on the legal regime of the public sector through the so-called automated administrative action.

Indeed, the actual value of Big Data lies in the ability to analyze and generate algorithms that produce, in turn, valuable and quality information in decision-making processes, also by public administrations, within its main functionality consisting of collecting a large amount of data to find repetitive patterns within them. Big Data, Artificial Intelligence, and other new technologies bring benefits such as the automaticity of systems immediacy of the response.

- Adaptability to new situations.
- Simplification of administrative action.
- Use of chatbots in citizen information systems.
- City mobile apps.
- Personalized dashboards for the citizen.

However, the massive use of these technologies & applications, especially Artificial Intelligence, allows us to obtain knowledge from an enormous amount of data, in many cases referring to citizens. In this case, special control over the use of these tools is necessary to ensure privacy and prevent fraudulent use.

2.7 Value-based Digital Government

The digital transformation opens up new opportunities and forms of social participation and processes of formation of public opinion, with the possibility of involving all members of society. Digital technologies offer new options for solving social problems and making governments and public institutions more efficient and effective. Society must take full advantage of these new opportunities.

The digital rights and principles outlined in the declaration will complement existing rights such as those enshrined in the EU Charter of Fundamental Rights and data protection and privacy legislation. They will provide a framework for citizens on their digital rights and guidance for EU Member States and businesses to address new technologies. It aims to help everyone in the EU make the most of the digital transformation.

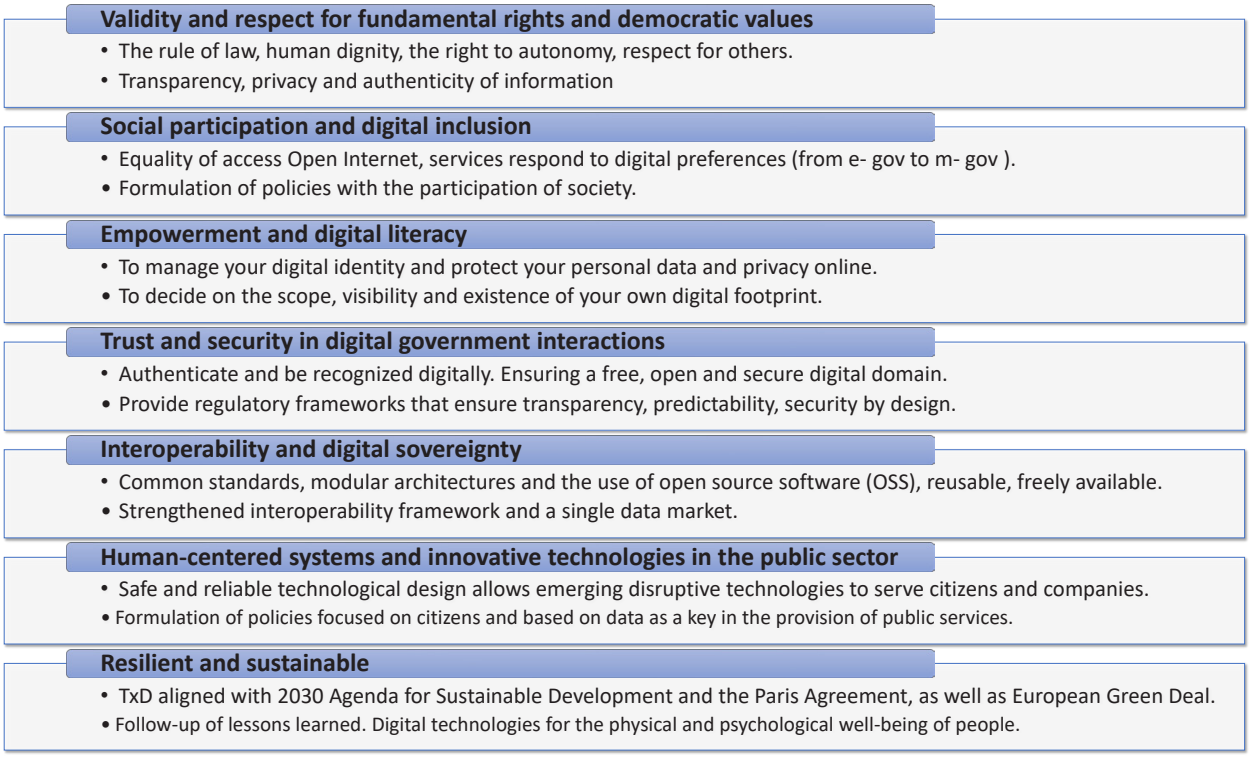
One example of value-based digital government is the Berlin Declaration on Digital Society and Value-based Digital Government[14] that takes the user-centricity principles formulated in the Tallinn Declaration on eGovernment[15] a step further by strengthening the pioneering role of public administrations in driving a value-based digital transformation.

The declaration acknowledges the public sector as an essential element for the European Single Market, and a driving force for new and innovative technological solutions for public services and societal challenges. It emphasizes that public authorities at all levels must lead by example to strengthen the tenets of the European Union.

To do so, the Berlin Declaration on Digital Society and Value-based Digital Government sets out seven key principles with related policy action lines:

- Validity and respect of fundamental rights and democratic values in the digital sphere.
- Social participation and digital inclusion to shape the digital world.
- Empowerment and digital literacy, allowing all citizens to participate in the digital sphere.
- Trust and security in digital government interactions, allowing everyone to navigate the digital world safely, authenticate, and be digitally recognized within the EU conveniently.
- Digital sovereignty and interoperability, like a key in ensuring the ability of citizens and Public Administrations to make decisions and act self-determinedly in the digital world.
- Human-centred systems and innovative technologies in the public sector, strengthening its pioneering role in the research on secure and trustworthy technology design.
- A resilient and sustainable digital society, preserving our natural foundations of life in line with the Green Deal and using digital technologies to enhance the sustainability of our health systems.

Figure 3: Berlin Declaration on Digital Society and Value-based Digital Government – 2020



2.8 Electronic Administration and SSC

Relations with public administrations are increasingly dominated by the use of new technologies and digital enablers: governments around the planet are finding in digitalisation a source not only to improve their relationship with their citizens but also to promote efficiency and effectiveness in improving public administration. The States are ready to lead key aspects in this transformation process through different government agencies.

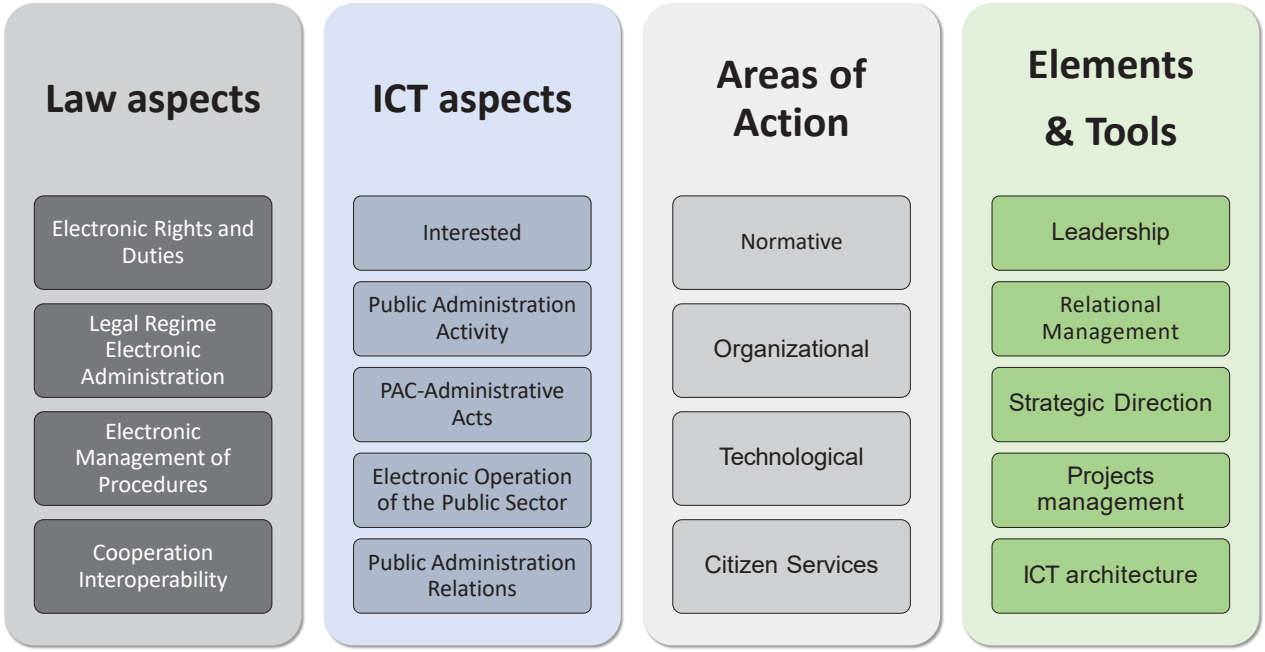
Plans that can be based on pillars and challenges:

1. Modernize Public Administration.
2. Achieve interoperability with different digital public entities and services.
3. Facilitate the digital interaction of public administration with citizens and companies.
4. Regulatory aspects and adaptation to new technologies.
5. Easy access to citizens' personal histories.
6. Strategic leadership based on easy tools and elements for public entities and citizens.

Digital security is an unavoidable component of the move in this direction and in achieving an authentic digital administration to meet the present and future needs of citizens. The Internet knows few borders or data protection legislation. Security against cyberattacks or digital scams such as the phishing of official pages requires shared governance of security and reliability on the network. Public administrations must get used to working together in a scenario of multiple interactions and where threats do not come from within their national borders.

In this context, administrative managers appear as faithful allies of e-government, facilitating and improving the relationship between administrations and citizens through a role of advice, mediation and management that, in addition, promotes digital inclusion and reduces the existing digital gaps in the population. Their role in extending cross-border digital government can be a success factor with their experience, knowledge and tools.

Figure 4: Electronical Administration Challenges



2.9 Privacy and data protection

Currently, there are many questions about the challenge of privacy in Smart Cities.

The integral management of data has become a reality that affects personal and collective life. A large part of the city's professional, economic and private activity occurs on the Internet. It has acquired a fundamental importance for human communication and for our life in society. Today, the risks and opportunities that the world of networks offers to citizens are identified. Public authorities must protect the citizens' rights in networks by promoting the equality of citizens and the groups in which they are integrated in order to make the whole exercise of fundamental rights in digital reality possible.

While "privacy" is an important aspect that must be considered for establishing a City Platform, there must be a compromise between privacy and citizens' privacy rights.

At the European level, the realisation and development of fundamental rights of protection of natural persons regarding personal data processing are set out in Article 8 of the Charter of Fundamental Rights of the European Union and in Article 16.1 of the Treaty on the Functioning of the European Union.

Previously, at the European level, Directive 95/46/EC had been adopted, the purpose of which was to ensure that the guarantee of the right to the protection of personal data did not constitute an obstacle to the free movement of data within the Union, thus establishing a common area of guarantee of the right which, at the same time, ensures that in the event of an international transfer

of the data, its processing in the country of destination is protected by safeguards appropriate to those provided for in the directive itself.

The centrality of personal information has positive aspects because it enables new and better services, products or solutions. Nevertheless, it also carries risks since information about individuals multiplies exponentially, is more accessible by more actors and is increasingly easier to process. At the same time, it is more difficult to control its destination and use.

The development of Smart Cities inevitably involves the processing of all kinds of information – including geolocation, traffic, energy consumption and the environment – much of which falls within the scope of the data protection laws and, consequently, its collection and use for this purpose are prohibited without the informed consent of the persons concerned.

That people make cities more efficient and sustainable will have a clear impact on the privacy of these people, even though they will be the primary beneficiaries of these services.

Some measures have indeed been agreed upon that would reduce the impact caused by the massive processing of information in the private spheres of individuals. So far, we can find abstract concepts of emerging interpretation such as the principles of Privacy by Design, Privacy by Default, or the principle of minimisation. However, the truth is that we cannot be held back by the search for, and continuous review of, the principles and technical solutions that allow smart initiatives to develop more safely.

What are the virtues of these advances? Which principles will benefit city dwellers in the future? And what, ultimately, are the dangers that mask this future? What are, or should be, the roles of government and the private sector, and what price will people pay for the privilege of living in a Smart City? Is it morally acceptable to impose exceptions to people's privacy in the public interest? How can we address the security risks associated with collecting and using private information for other purposes? Our current policy and legislative initiatives are feasible to facilitate innovation and the development of Smart Cities?

Due to the exponential growth of Big Data that is gradually being stored in smart city platforms, special attention should be given to reflecting on the concept of profiling**.** This involves creating profiles of users or consumers of various public or private services to obtain large amounts of information through data-mining techniques, analysing common behavioural patterns to offer advanced solutions, and optimising resources according to statistical inferences. Examples of profiling could be:

- Through intelligent transport tickets with NFC (Near Field Communication) technology, profiles can be made on a person's trips, habits and customs based on the specific use of urban public transport.
- Water consumption may indicate how many people can live in a house.
- The energy consumed by home, to discover what schedules they have or their lifestyles.

According to the Regulations and similar legislation, profiling should only occur with a person's consent; unless it is treated as the primary purpose derived from a contractual relationship.

The problem is that, in many cases, obtaining and managing consent by providing timely information is operationally ineffective or, at worst, simply impossible because these data must be used at the time of capture in order to meet the goal. To this end, it is essential that legislation defines procedures for the dissociation or anonymization of personal data outside its current scope and is only permitted in those cases where it cannot make disproportionate efforts to identify a person.

It should be noted that the concept of "person" developed by software expert Alan Cooper, through the creation of an intermediate level of personal data, does not concern an "identified or identifiable person", but rather archetypes or models of people who meet several common characteristics and specific needs. In this way, they provide an easily analysable profile without referring to any actual person "behind" the processed information and, therefore, protect the link with the subject's identity. Once officially recognized, methodologies like this would avoid deficiencies in the collection of consent concerning information that "have to borrow in interest" when processing your data or in the use of expensive security measures. It would not be to process Personal Data of identifiable individuals and, therefore, solutions could be implemented in the community's interest.

Consequently, we must work towards consensual solutions that respect the privacy of individual people and can leverage data analytics to improve infrastructure management, quality of life, and coexistence among people.

2.10 Regulatory framework of local competences

From the strictly local, legal-organizational perspective, the actual consolidation of these new urban models for developing an SSC requires open, plural and efficient innovative governance structures. It is not a question of urging organizational change at the local level but of really moving in that direction to adapt to citizens' general interests.

The first problem is that no specific local competences title attributes globally and directly to the municipality the set of competencies (regulatory and management planning) necessary for implementing or achieving the (informal) character of the city as a Smart City. A greater capacity for action is recognized logically from the self-organizational and organizational freedom of the services of local authorities. However, in the end, the inoperability results from structures, services or dependencies without adequate substantive competencies.

The diffuse concept of the Smart City implies, at least from a legal perspective, the existence of services, infrastructures, and smart networks (i.e., sustainable, efficient and controllable networks) of urban transport and mobility, of people and vehicles, of water supply and evacuation, recovery and waste treatment. The general framework is, obviously, the global consideration of the global city system – and, therefore, the competencies and normative group on urbanism and physical planning

of the city – and the constant improvement of the quality of life of all its inhabitants (environmental protection and urban sustainability) through its widespread use.

However, when they become a reality, these great objectives need the capacity to compete and the organization of the organization/provision corresponding to these public services. The achievement of the objectives (implementation and development of the related services and infrastructures, plus the control and evaluation of their follow-up) for consideration as an intelligent city thus imposes the interweaving, competence and substantive, of generic titles (basically in urban and environmental matters) and sectoral.

In this sense, in the Spanish system, the primary legislation of the Spanish local regime continues to recognize as competences of the municipalities, even in terms of the legislation of the state or the corresponding to Regional Government, generic nuclear matters in these objectives such as urbanism, urban environment or protection of public health, along with other more specific ones also clearly linked to the achievement of Smart Cities (such as the supply of household drinking water and wastewater evacuation and treatment, road infrastructure, traffic, vehicle parking and mobility, and urban collective transport).

The combination of compelling competence titles should allow a wide field of play and innovation in the hands of local authorities to implement urban intelligence initiatives (beyond local services that are legally qualified as mandatory).

3 City & ICT governance

Cities worldwide have vastly different backgrounds, priorities, capabilities, strengths, and strategic goals and objectives, which means there can never be a single global solution to their intelligence and sustainability needs.

Successful implementation of an urban digital infrastructure depends on keeping the needs of citizens, the requirements of quality of life, and expectations, above all.

- What technological complexity do they suppose for a small city? And on what financial level?
- How does the size of the city influence the launch of urban digital infrastructure?
- How to optimize existing resources to generate savings for citizens, companies and Public Administrations?
- What mechanisms of citizen participation and democratic mechanisms permit the public and all other key stakeholders to have a voice in setting the general urban management?
- How should the smart, urban digital infrastructure be used in data management?
- What will be the return on investment made in cities?
- What ethical and legal measures should be taken in cities where private companies and external agents control the management of the Platforms to the organization?

The introduction of ICT in cities has been taking place progressively as connectivity and technology become more capable of being applied to administrative activity and improving the provision of basic services such as the integral water cycle, mobility and solid waste management.

In this evolution, the information systems to support the administrative activity have been developed within their own ICT infrastructure, and the technology in the provision of public services is usually provided by the contractor of the public service.

In both cases, the development of these ICT solutions has been consolidated as a fundamental support element in the provision of services. Nevertheless, the conception of the solution generally had an isolated orientation in the functionality of the solution and in the development of its layers – including data, components and interfaces. Except for regulatory requirements, interoperable solutions were not built from scratch.

IT governance is defined as "a governance view consisting of ICT business governance (ensuring that ICT supports and enables the business strategy to be carried out) and a functional IT governance view (ensuring that the IT function itself is executed efficiently and effectively)."

The very conception of information systems to support the provision of administrative services and public services frequently offered excellent solutions with little capacity for communication and cooperation among them.

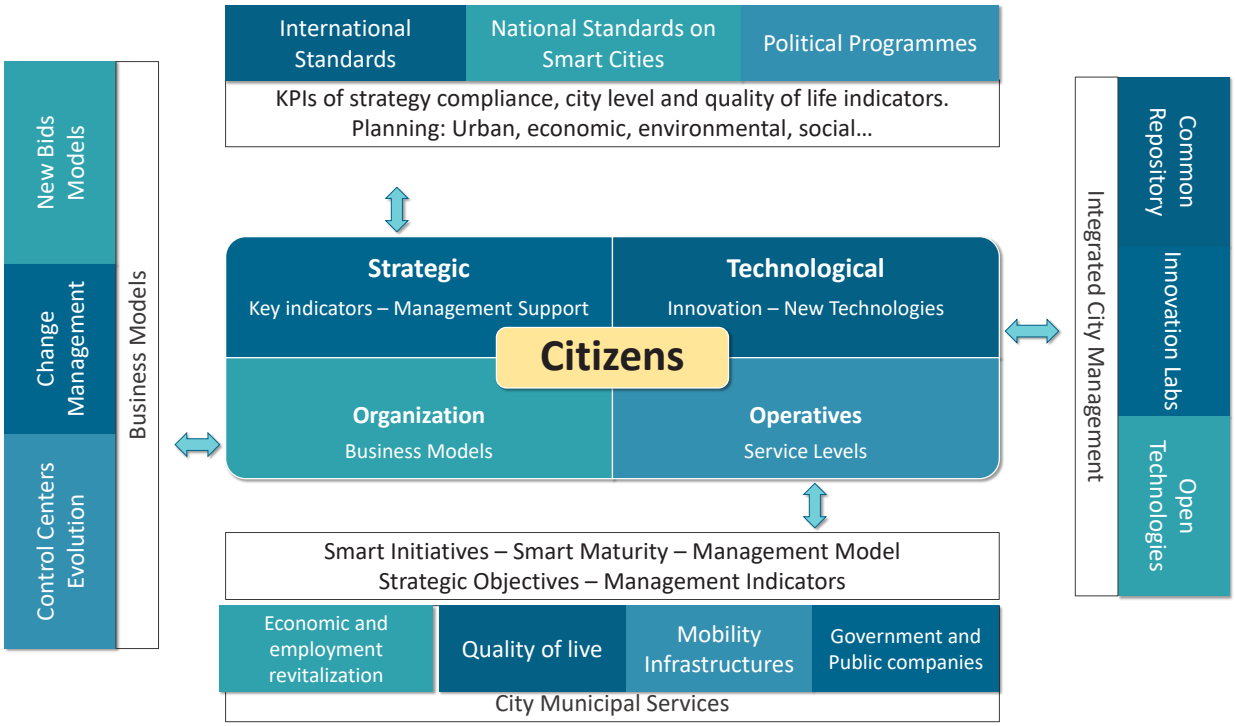
The evolution of technology and programming languages allow us to conceive the ICT architectures of service-oriented cities, which, in turn, allows us to evolve towards corporate transversal elements to offer homogeneous services throughout the life cycle, as well as the creation of services by information systems to cooperate with other information systems with the appropriate security mechanisms.

This chapter describes ICT elements that must be addressed by a city in a corporate perspective, namely the importance of strategic ICT governance planning to align with the challenges and to offer the necessary ICT services effectively and efficiently.

3.1 Conceptual vision of a Smart City strategy

A Smart City strategy must be focused on citizenship as a core element of all the strategic, organizational, technological and operational actions necessary to obtain a holistic vision of the city that enables its sustainable and resilient evolution to be controlled.

Figure 5: Smart Strategy



Having citizens at the centre of the Smart City strategy requires developing actions in the following areas:

- Strategic: The solutions resulting from the plan must offer tools and data to support the strategic and operational decisions of the political and official leaders of the different municipal areas, as well as support for the evaluation of compliance with the Sustainable Development Goals and city strategy.
- Organizational: There are different models of implementation of an integrated city management platform, either on new contracting models, where different services are concentrated or by the implementation of a data platform that allows the integration of the technology on which to transform the contracts. In any case, we must take into account the management of change and the unification of the control centres that technology already allows.
- Operational: The city strategy must start from a knowledge of the current state of the introduction of ICT in the management of municipal services. To this end, it would be possible to carry out a consultancy that describes the smart initiatives of the services, their level of smart maturity, their management model and the introduction of strategic direction in the definition of objectives, establishment and monitoring of management indicators.
- Technological: The service-oriented architecture, the market proposal of cloud or hybrid solutions, the constitution of a common data repository, the use of open technologies and the creation of innovation laboratories must all be addressed in the Smart City technology strategy.

Even so, the addition of other users of the city, such as tourists, to the centre of the smart and sustainable city strategy, justified by their role of service users when traveling, results in the proposal of a collection of digital solutions targeting not only isolated tourism issues but also main public problems and market failures, since the travel cycle constantly interacts with cross-cutting elements of the city alien to the tourism activity. This reality stresses the need to include in the strategy conceptualization, a diversity of stakeholders to balance the secluded interests of different economic sectors, being tourism the perfect subject to bring them together thanks to its multisector reach.

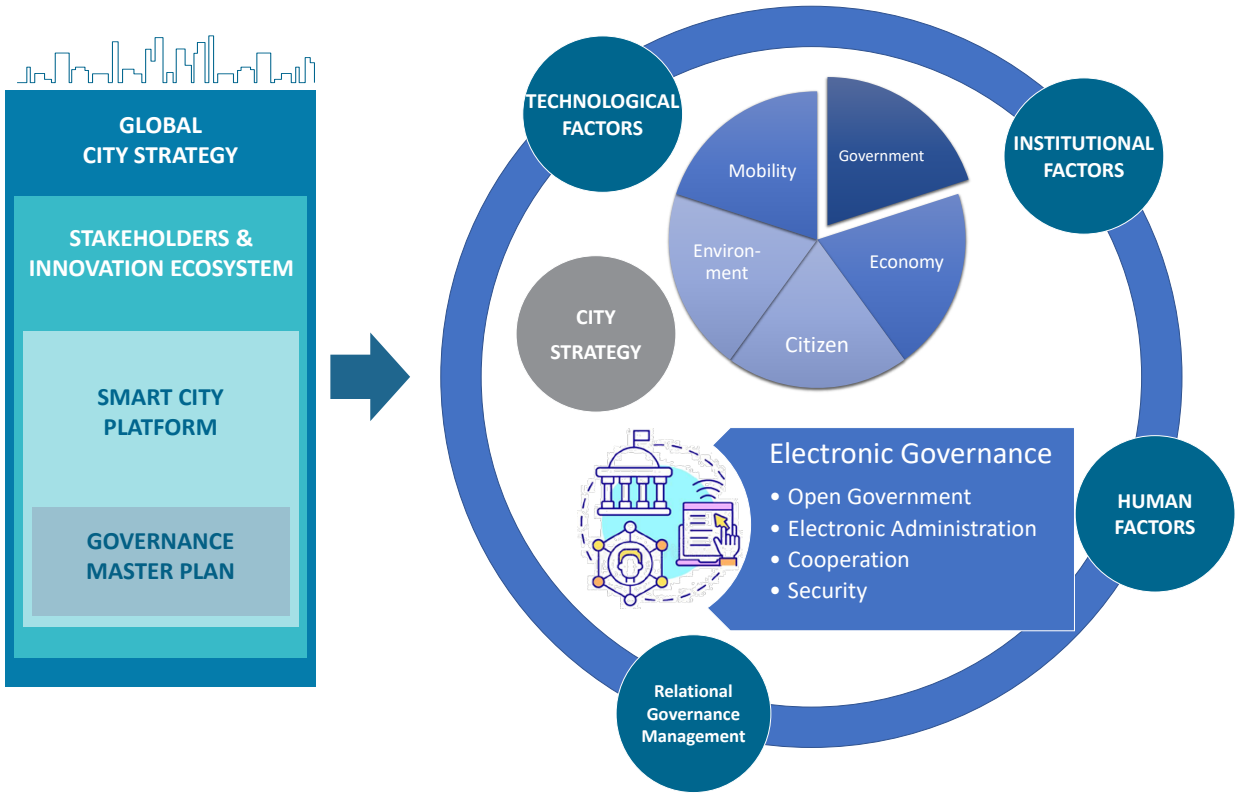
3.2 Strategic Management in SSCs and ICT

The fulfilment of the Sustainable Development Goals and any transversal challenge requires institutionalizing strategic management in cities. The strategic direction allows delimiting the main missions to fulfil the city model in terms of climate change, carbon-neutral, the attraction of talent in general in environmental, social and economic factors.

It is difficult to provide a single guide to strategic direction in the ICT field given that each city has its own characteristics in terms of:

- Institutional Factors: National and regional laws in the ICT field, the organization of the city itself, the vision and leadership, the ICT ecosystem and talent of the socio-economic environment directly affect ICT strategic planning.
- Technological Factors: The city's own ICT infrastructure, proprietary information systems, the existence of a service-oriented architecture, the common electronic services of the region or the country directly shape the ICT strategic planning.
- Economic-Human Factors: The creation of a robust and scalable ICT infrastructure requires stable human and economic resources over time.

Figure 6: Strategic Management



Additionally, an ICT strategic direction will be useless if it is not included in a city strategy, where public policies are defined to achieve the city model in a limited period.

Nowadays, a large part of the policies of the urban agendas has innovation missions to support them, with the support of the socio-economic ecosystem. Innovation missions from a city perspective will require a strategic Smart City plan supported by the ICT governance master plan.

3.3 Smart City Offices

The process of the digital transformation of a city must be endowed with sufficient human and economic resources, bearing in mind that the data infrastructure to be created will be one of the most important infrastructures in the city.

Creating a Smart City Office or a specific section within the ICT or innovation departments of the city is necessary for a successful transformation process. The following list shows a proposal of competencies that these offices should have, and that should be approved by the local government boards.

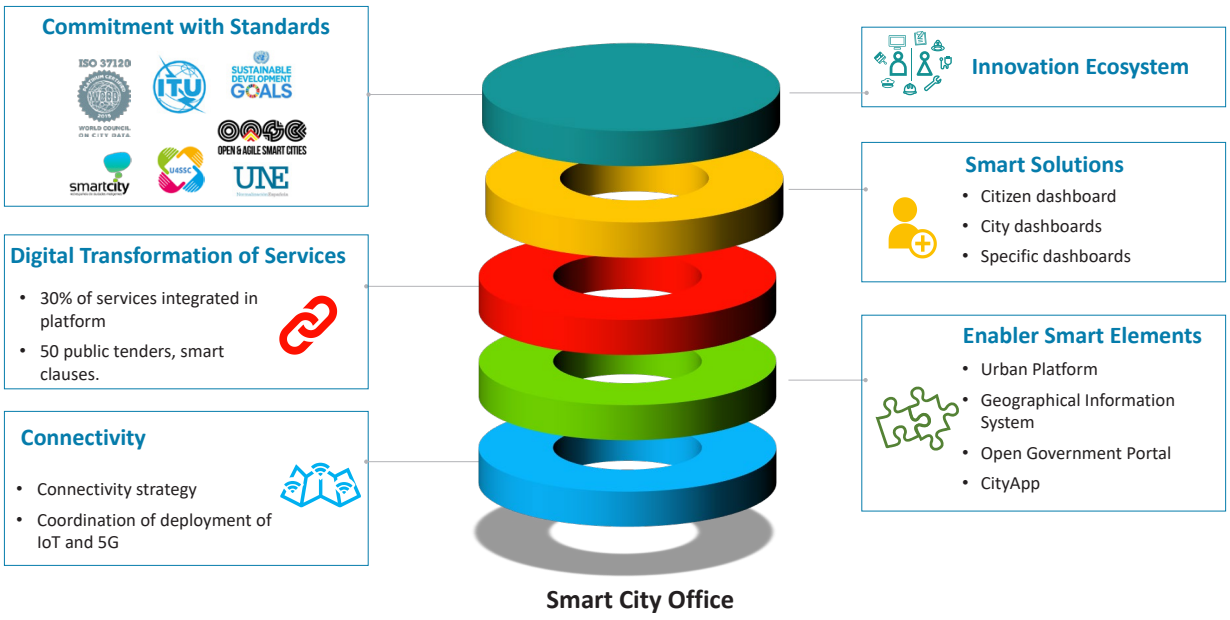
1. Advice, guide and inform in the Smart City model and in the different municipal strategies in the field of Smart City, science of the where, and connectivity.
2. Coordinate and direct the analysis, design and management of Smart City projects.
3. Management of computer projects of the Internet of Things and introduction of ICT into public services.
4. Design, control and maintenance of the technological architecture that ensures connectivity to citizens.
5. Cooperate in Digital Transformation projects.
6. Responsibility and management of an integrated city management.
7. Responsibility and management of the Municipal Geographic Information System.
8. Cooperate or coordinate in ICT projects related to the territory and georeferencing.
9. Development of methodologies and work regulations related to the introduction of ICT in public services.
10. Direct and coordinate the integration and functional compatibility of projects with computer systems and Smart City technologies.
11. Collaborate in the management and coordination of Smart City R&D financing initiatives and programs.
12. Coordinate the technical staff in the actions related to the implementation of projects and their subsequent operation, maintenance and continuity of operation.
13. Training of new products and technologies in its field of action.

3.4 SMART Areas of Action

The transformation of data into specific services and elements for decision making requires structuring the actions of a Smart City Office in the following areas of action (see *Figure 7*):

- The smart enabling elements (integrated city management platform, information system, connectivity with Internet of Things devices, Big Data, Artificial Intelligence system).
- Intelligent solutions (open data portal, unified dashboards, citizen dashboards, geoportal, CityApp).
- The support of all the above elements is the core of the innovation ecosystem, internally as well as externally.
- The project team is necessary for the support and operation of the above services, as well as support for the digital transformation of municipal services in their non-administrative field.

Figure 7: Smart City Action Layers



On the other hand, the development of a Smart City strategy involves considering not only the enabling elements such as a city platform and sensors deployed in the municipality but also all the elements that are around this platform that acts as a backbone. The deployment of these enabling elements is the first step to subsequently allowing the creation of intelligent solutions ranging from dashboards for monitoring key indicators of the city to transformative solutions that allow the digitizing of the different municipal services to have greater control over them and to ensure that this results in improvements and efficiencies for the city.

All smart services provided must consider connectivity as a fundamental asset for added value services based on geolocalised and personalised interaction. For this, it is necessary to define a comprehensive connectivity plan for the city which consider the deployment of devices (IoT), new elements and technologies, issues regarding security, operation, administration and maintenance of this ecosystem in the public space.

Finally, all these elements must permit the creation of an open innovation ecosystem in which the corporation can interact with third parties, allowing the development of new solutions that maximize the benefit obtained by the city.

4 Urban technological reference architecture

As the citizen is the axis of municipal activity, the efficient management of resources and the creation of new services in an SSC requires a conceptual model that semantically describes the relationships between people and the physical world.

There are different visions for the digital transformation of an SSC: the functional vision, the management vision, the physical vision, and the business vision.

City communications and technology solutions are based mainly on international and national standards. These standards define an architecture model based on layers wherein each layer's common functionalities are grouped, and standardized interfaces are defined between them.

- What should be the ICT architecture model of a Smart and Sustainable city?
- How to face the new forms of connectivity?
- What benefits can the implementation of an urban digital infrastructure bring to citizens in the short and medium term?
- How to design a platform or an integrated management strategy for a sustainable and intelligent city so that the benefits exceed management costs?
- What layers should be present to improve the integrated management of the city?
- What are the enabling elements of the city's digital transformation that organizations should have?
- How are information silos broken in organizations? What happens when information systems are proprietary and the transmission of information between systems is complex?
- What strategic vision and review systems must be implemented in cities so that continuous technological development does not mean that the town's medium/long story is based on patches?

4.1 Introduction

The efficient management of the resources and services available in an SSC entails important organizational, technological, and operational challenges. However, the achievement of the city's transformation objectives is linked to the ability to have a technological ecosystem that enables automated and sustainable management of resources and provides useful information for decision-making.

The reality of cities is complex and heterogeneous in terms of their own urban nature, degree of technological development and available resources. The path towards a technological architecture of reference that allows the rapid development of applications, and the sharing of resources is a medium to long-term task that must consider the new technological paradigms, sustainability, re-usability and interoperability with other external actors.

The greatest difficulty for this transformation is to identify elements that already exist (e.g., sensors, services, and social networks), define how to share resources and data, so that they can interact to create or improve the services of the city and finally, to have a unified technological infrastructure that allows interoperation with different types of existing legacy platforms.

This situation has worsened as citizens have demanded increasingly complex services that often require the sharing of information in real time among different internal departments and external actors.

It has been considered convenient to describe a target technological architecture through an ideal abstraction of a city ecosystem based on elements and interactions, and then, a real ICT ecosystem with the different components that exist or may exist (administrative systems, databases, geographic information system, smart city platform, etc.) on which services and applications of value for citizens and process improvement are built.

In the Report of the ITU Secretary-General for the Sixth World Telecommunication/ Information and Communication Technology Policy Forum 2021 (WTPF-21),[16] ITU-T defined six priorities, solutions and technologies that have the potential to transform areas as diverse and critical as education, health care, finance, mobility, agriculture, energy, accessibility, and connectivity. These are: Artificial Intelligence, the Internet of Things, 5G, Big Data, OTTs and finally, the development of new solutions for connectivity. Cities will be major beneficiaries of these developments as five of the six priorities are directly applicable in an SSC.

In this context, new paradigms such as the Internet of Things, Artificial Intelligence, 5G, Big Data and advanced connectivity offer high-impact solutions, but also entail new challenges that must be faced in an organized way under a consistent technological architecture.

Under this prism, facing the above challenges and obtaining the value of these technologies requires a macro approach that allows the user to:

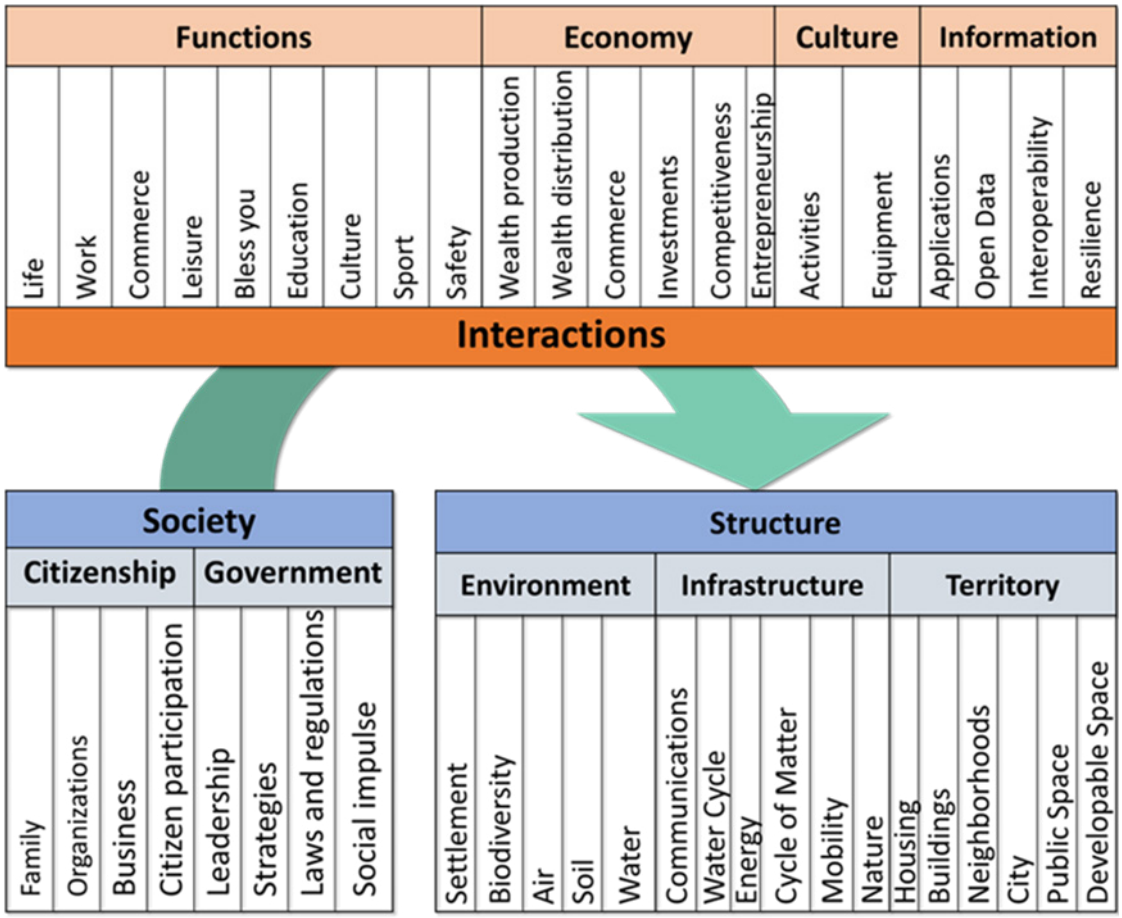
- Define a conceptual model that semantically describes the relationships between people and the physical world.
- Provide intelligence to different managed objects, physical and logical infrastructures, distributed throughout the city.
- Transmit the data of these infrastructures with guarantees of security and reliability.
- Collect large amounts of heterogeneous information, mostly in real time.

- Process and interpret this information to monitor the city, to be able to identify synergies and improve efficiency.
- Generate the economic and social value of data to serve municipal objectives and decision-making, collaborating in the advancement of the economy and the digital space of data and services.

4.2 SSC Taxonomy

The city is a dynamic system in permanent evolution, with multiple and complex interactions among people (citizens, visitors) and the environment (physical world). A system of these characteristics can be defined semantically[17,18] as a set of possible relationships between the physical structure of the city (natural environment, infrastructures, territory) and society (citizens, institutions) through a set of interactions that allows society to use the resources of the structure to develop citizen activities (e.g., work, commerce, leisure, health, education), generate wealth and share information. *Figure 8* describes a taxonomy of the conceptual model that relates to these three domains.

Figure 8: Conceptual model of the semantics of a Smart and Sustainable City



The ***structure system*** encompasses the non-human physical elements existing in the city, and this system is, in turn, subdivided into three subsystems: environment, infrastructures, and territory, each with its own attributes and indicators.

- *The environment* describes the natural conditions existing in the city and where it develops. It is composed of nature, animals and plants, plus the three basic elements of biodiversity: air, land and water.
- The *infrastructures* encompass the set of physical elements that allow citizens to obtain the resources they need or that allow their management within the city. The most representative infrastructures are telecommunication networks, the water cycle, energy, the materials cycle, mobility and nature understood as information about non-human living elements at all scales.
- The *territory* defines the public and private structures where citizens live (house, building, block, neighborhood, etc.) and the public space that surrounds them (streets, squares).

The ***Society system*** refers to individuals and the way in which they organize and relate, as well as to their government.

- *The citizen's subsystem* encompasses people in the broad sense as individuals: citizens or visitors and their social structure, families, private organizations, businesses, and so on.
- *The government subsystem* refers to the political-administrative structure of the city and is responsible for the policies and regulations that facilitate the development of the city. In this case, the term "governance" is used to evaluate the effectiveness of government.

Interactions are the activities that society carries out with structures, and that can be analysed and measured as information flows.

- *Urban functions*, including work, commerce, leisure, health, education, culture, sports and security.
- *The economy*, including the activities of production and distribution of wealth, competitiveness, innovation, and entrepreneurship.
- *Culture*, including the non-material assets of the city, values and traditions.
- *Information*, including indicators, processes and operating models and data, as well as their management, dissemination and sharing (interoperability).

Although conceptually the semantics defined above permit the describing of society's relationship with the environment, the number of possible interactions and, therefore, possible intelligent solutions, is vast and heterogeneous. These can range from simple applications such as temperature monitoring to much more complex ones such as integrated traffic management based on environmental and/or congestion criteria.

On the other hand, the municipal organization has historically developed based on defined areas of activity. In most cases, it corresponds to municipal organizational structures such as water supply, waste collection, environmental management, and public lighting. There are also external systems of a heterogeneous nature that are managed by third parties such as transport services, tourism and social networks.

It is common for municipalities to have many self-contained vertical solutions, known as "silos", which solve specific problems. Although they are usually simpler to implement, they cannot solve the demand for more complex services that, in many cases, require the sharing of information in real time among different internal departments and external actors.

This legacy model has become too complex to manage and is not suitable for processing the enormous amount of information generated by the connected elements. It also hinders proper decision making, which, in many cases, may not be aligned with other areas or departments of the city.

Consequently, a horizontal solution that supports different business applications enables the rapid creation of new services and the sharing of information between areas and external actors. It also eliminates duplication in communications and hardware and software, is flexible, reduces the costs of operations, administration and maintenance, and is an excellent approach to solving the present and future needs of the city in an orderly way.

Designing a scalable, consistent, and secure technological ecosystem that enables the flexible incorporation of new functionalities implies:

- The definition of a reference architecture based on services.
- An integrated and standardized model of information.
- Unified operation and metrics.
- Performance indicators that allow the profitability of the necessary investments to be evaluated.

This architecture, with minimal changes, must be able to adapt to present and future needs. Aspects such as the introduction of converged networks like 5G,[19] IoT,[20] Cloud Services, Big Data, Artificial Intelligence and blockchain represent new opportunities to use technology to improve efficiency and create more and better public services.

However, there is no single architecture or reference platform to respond to these requirements. The task of choosing a technological solution is not without difficulties since it depends, among other factors, on the available budget, the necessary functionalities in the short and medium term, the ease of migration of existing systems to the new architecture, standards (open or proprietary), and finally, on the ability to generate interdepartmental synergies that reduce costs and justify the investment.

Such could be the case for the tourism activity. As mentioned above, the setting in motion of semantic models able to capture the reality of an urban ecosystem constitutes a valuable opportunity not only for the efficient and sustainable management of resources in the overall local economy but also, in a tourism context, as a direct way towards the competitive evolution of the tourism offer of products and services. Through a model able to identify give proper meaning and establish relations inside and outside the tourism-related terminology, the application of a semantic standard allowing interoperability is possible. By meeting this essential condition, in which the tourism offer, and public services are capable of speaking the same language, a new digital configuration of the city as a destination, able to provide more and better services tailored to each tourist needs, is within reach.

4.3 Reference technological architecture

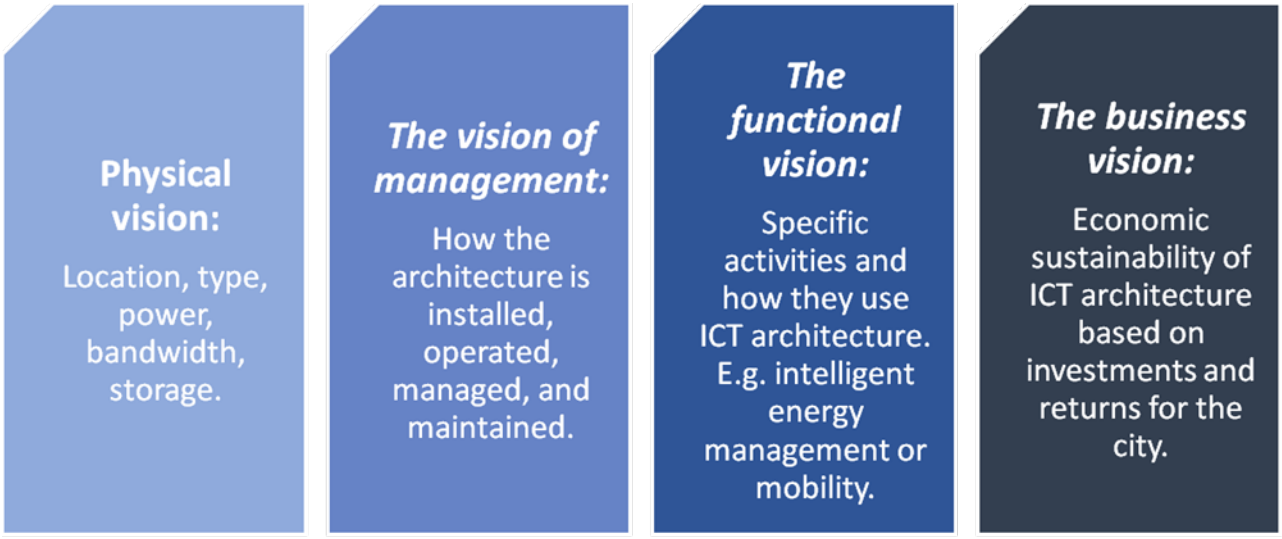
We can define the information and communications technology (ICT) architecture of a Smart and Sustainable City as a complex set of components, functional blocks, hardware, telecommunication networks, services and applications that interact with one another and whose influence is capital for the correct development of the Smart City. This architecture must cover heterogeneous geographical areas, use multiple technologies, be valid for different types of cities, be safe and available, and have to operate over time. It must also provide services that allow the building of valuable applications for citizens, companies, administrations and visitors.

The basic principles with which the ICT architecture must comply are that it is standards-based, flexible, scalable and fault-tolerant. It must also provide security, information protection (privacy), advanced services and standardized ability to exchange information with internal and external systems.

There are different visions (see *Figure 9*) to address how to describe, identify and classify ICT systems and subsystems along with their relationships. Each of them aims to offer an approach oriented towards different interest groups.

- *The functional* vision: Focuses on aspects related to specific activities of the city and how these activities use ICT architecture to solve specific needs. For example, intelligent energy management or mobility.
- *The management* vision: Focuses on how the architecture is deployed, operated, managed, and maintained. It also applies to the description of services, logical security, manufacturers, information management and usability of the architecture by citizens.
- *The physical* vision: Focuses on the location, type, power, bandwidth, storage and other characteristics of the elements of the computing and communications architectures.
- *The business* vision: Focuses on the economic sustainability of ICT architecture based on investments and returns for the city.

Figure 9: Vision of the ICT architecture of an SSC



Representing these aspects in a unified ICT architecture is complex due to the great variety and heterogeneity of the components that constitute it, and also to the difficulty of its development and implementation. All these components need to be modelled to ensure that the ICT architecture of a Smart City is complete and logical and meets the required business objectives.

In addition, different industry players are involved in the development of the architecture: equipment manufacturers, telecommunications operators, software companies, systems integration, and developers of business solutions.

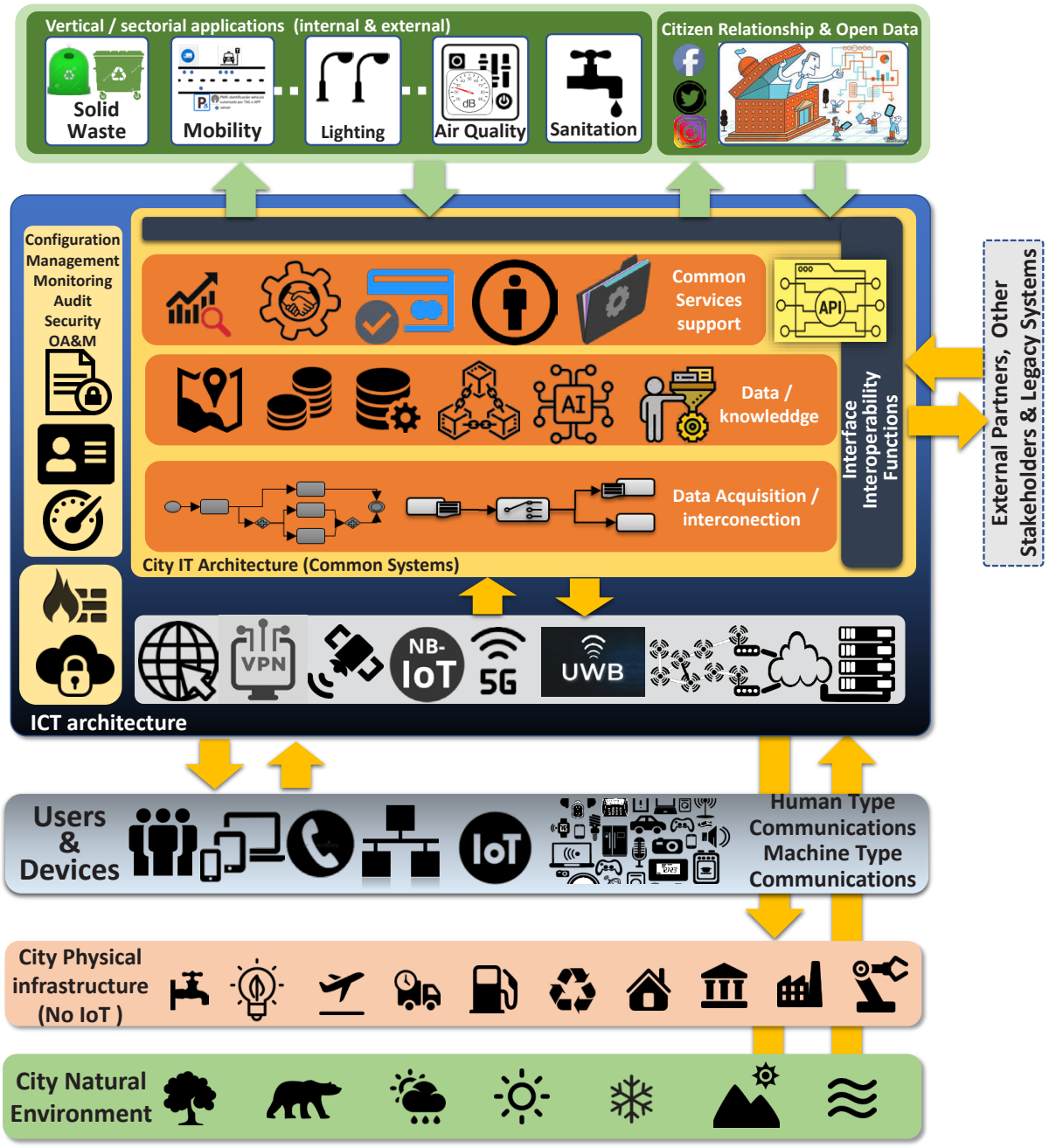
Due to the heterogeneity of the different components of the architecture, a hierarchical classification model has been established by a similar group of functionalities and defining relationships with other groups. This "layering" model is commonly used in industry and provides flexibility and scalability:

- It is easier to design and operate each layer separately than to design and operate the entire architecture as a single entity.
- Each layer can be defined independently of the other layers and classified based on similar functions.
- Each layer has its own functions and establishes relationships with adjacent layers or with the external environment through a client-supplier model.
- Each layer can possess its own operation and maintenance capabilities, as well as safety and security functions in the event of failure.
- A layer can be added to or modified without affecting other layers from the architectural point of view.

Figure 10 proposes a conceptual model that tries to materialize the city semantics described in previous sections in a model based on layers. This architecture model allows users (people,

intelligent machines, and processes) to establish relationships among them (bidirectional human-human, human-machine, and machine-machine communications) and with the setting (non-ICT physical infrastructure and natural environment).

Figure 10: ICT Architecture of a Smart City (own elaboration)



Natural environment. This layer contains the abstraction of the environmental objects that characterize the city and are relevant to the deployment of physical infrastructures. Orography and climatology are examples of this layer.

Non-ICT physical infrastructures. This layer contains all the physical elements necessary for the proper functioning of the city, which can be managed by the ICT infrastructure, and which allow citizens to obtain the resources they need. Buildings, roads, energy supply, water or waste management are examples of this layer.

Users and devices. This layer allows the interconnection between the environment, machines, infrastructures and people to ICT infrastructure and non-ICT physical infrastructures. The layer is composed of the users themselves (society) and the devices (terminals) that are used by people and machines, together with the models of relationship that can be established between them: between humans (telephony, social networks), of humans with machines (access to databases, sensors or systems), and of machines with one another (automatic acquisition systems, processing and action or exchange of data with other systems and/or control). Conceptually, these types of communication have been defined as HTC (human-type communications) for interactions where humans intervene and MTC (Machine-Type Communications) for the rest.[21]

In a broad sense, a device can be defined as a physical or logical element with communication capabilities and optionally with data detection, actuation, acquisition, storage and processing capabilities. The devices obtain different types of information and supply it to telecommunication networks for further processing. Some devices can be bidirectional and can execute operations based on the information received from the telecommunication network.

Mainly because of the reduction of device costs and connectivity, there has been an enormous growth of connected elements that impose new challenges on telecommunication networks due to their enormous number and behaviour, with very heterogeneous, and in many cases unpredictable, traffic patterns.

ICT Architecture. This layer allows the exchange of information between users and devices, offering common functionalities that are necessary to develop valuable services and applications such as vertical applications (e.g., smart waste collection, lighting, and intelligent mobility), as well as those related to models of relationship with society (e.g., people, tourism, administration). Within this layer, different sublayers and functional blocks have been defined arbitrarily. In the proposed model, the communications layer, the IT architecture layer, and the advanced services and applications layer have been defined.

- **Communications (connectivity)**. This layer contains the physical and logical elements necessary to ensure that devices and people can exchange information with guarantees of quality and safety. Aspects such as geographical coverage, low consumption, and cost of devices, together with emerging technologies and novel traffic patterns not sufficiently characterized such as 5G or NB-IoT,[22] generate new opportunities that must be addressed with solutions adapted to this new demand.
- **IT architecture (common systems)**. This layer contains the physical and logical elements that allow the offer of different services common to the vertical application layer where the business solutions reside. They also allow the exchange of information with other systems, carry out

adaptation processes with the telecommunications network and guarantee the security and reliability of the data. There are different approaches to the design of this layer, also called a "city platform", as it is a key element in the development of IT solutions for SSCs. Although there are different approaches that will be discussed in successive chapters, the guidelines emanating from the Recommendations ITU-T Y.4200[23] and Recommendation ITU-T Y.4201 have been considered of greater[24] relevance where the high-level requirements and reference architecture of a City Platform are defined. These recommendations define the following sublayers:

- **Acquisition and interconnection**. This contains the mechanisms for obtaining data from different sources of the Users and Devices Layer from the Communications layer. This layer can perform a semantic process of abstraction of the data to make it independent of the physical device, as well as transform the received data into structures with additional context information to facilitate its management by upper layers.
- **Data/knowledge**. This contains the mechanisms for the storage, processing, management, and use of large volumes of information. This sublayer includes tools that allow the movement of large amounts of data, processing, and analysis functionalities to generate new data sets or complete existing ones. There are also analytical and real-time processing tools, geospatial processing, Artificial Intelligence, Big Data, blockchain coders, and others related to information management.
- **Common Services Support**. This sublayer provides more complex common services or functional blocks that can be used through the interoperability layer. These functional blocks can serve as Common Building Blocks that can be used by the Sectoral Application Layer. Examples of this can be payment systems, authentication, and access control.
- **Interconnection and Interoperability**. This sublayer offers open and standardized interfaces on the functional blocks of the sublayers of knowledge and service support by adding the necessary security policies. It also allows services to be built from the data and favours the rapid development of vertical (sectoral) applications, as well as the exchange of information with external systems through APIs or adapters. The integration of the systems inherited from the City Council itself, with external actors (through the corresponding integration contracts) and with other cities that have a standardized architecture deserves special attention.
- **Control, Quality of Service and ICT Security**. This sublayer contains the mechanisms that allow the proper functioning of services and applications, provides control of the use of infrastructure resources, guarantees the quality of communications, mobility, and security of these (security of the physical infrastructure, security of the logical infrastructure, control of access to resources and privacy of information). It also includes auditing functions, physical and logical configuration of the infrastructure and the operation, management, and maintenance of infrastructure elements.

- **Services and Applications**. This layer contains the Smart City applications that are offered to society or devices and that use the resources of the ICT infrastructure. Located in this layer are the vertical municipal applications such as transport, mobility, electronic administration, tourism, waste management, energy, and water. New, advanced applications can be developed in an agile and efficient way since the architecture provides re-usable common functional blocks and an accessible global data repository.

In the case of the tourism municipal application, it must bring together a range of digital services aimed at current public problems and market failures throughout the traveller cycle, on the digital and physical levels. Moreover, it needs to be capable of a city-scale management with a great number of SMEs connected and monitored, accelerate the digitalization of key processes, improve the tourist experience, reduce the carbon footprint, boost business figures and generate prosperity for residents, contributing to the urban space evolution towards a competitive model based on data and algorithms.

Existing data space initiatives from international organizations such as IDSA and Gaia-X would also enrich the IT architecture layer since these organizations provide standards for a data exchange reference architecture, including a governance model and adoption strategy that ensure vital issues such as trust, security and sovereignty.

This interoperability mechanism, which allows resource and data sharing, consists of a multilevel reference architecture that begins at a bottom level, but allows the merger of different data spaces of the same sector of activity to give place to an industrial data space. From this level, the generation of improved services that either increase sales or reduce costs is easier through a collaborative process. This kind of structure allows certain sectors like tourism to make a better case for implementing such interoperability mechanisms given not only their shared public and private nature, but also their multisector reach, constituting an improved resource- and data-sharing method that tackles a great current challenge for digital transformation.

5 The Connectivity of a Smart and Sustainable City

Deploying an advanced ubiquitous telecommunications infrastructure to support the connectivity of thousands of heterogeneous devices deployed in an SSC is a big technological challenge that entails significant deployment and operation costs. The constant technological evolution allows the use of different connectivity options but also the risk of a rapid obsolescence.

The transformation of the municipal communications network and the management of public space need to be defined based on the possible interactions between people, people with devices or devices with each other.

- What are the general needs of people and IoT devices in an SSC?
- What are the main connectivity scenarios in an SSC?
- What are the main services that and SSC should offer in terms of connectivity to citizens, municipal officials, and other actors?
- What would be the simplified model of a municipal corporate network?

5.1 Introduction

One of the biggest technological and operational challenges facing the development of an ICT ecosystem in a Smart City is to have an advanced ubiquitous telecommunications infrastructure that allows the connectivity of thousands of users, heterogeneous sensors, and devices with the quality, security and availability required at a reasonable cost.

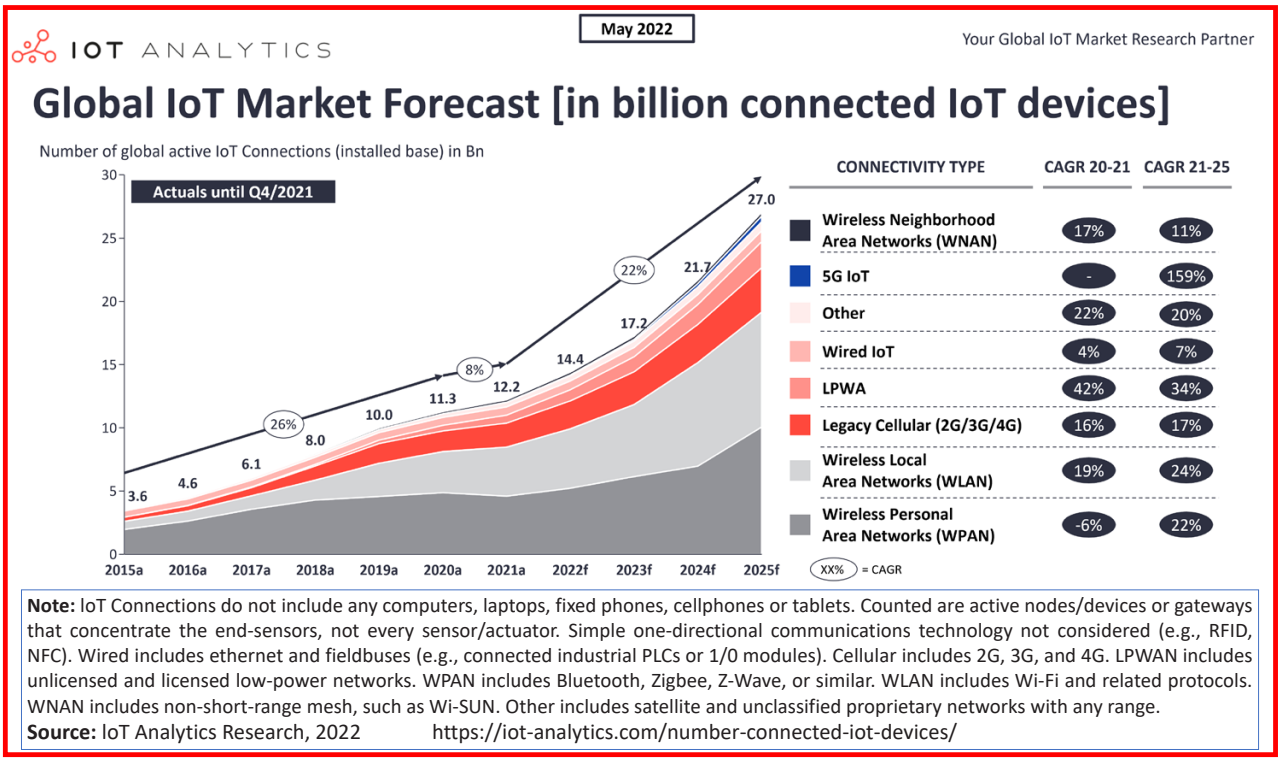
In many cases, cities have historically organized their communications based on meeting operational connectivity needs for officials' access to centralized municipal information systems and sharing resources such as corporate telephony service or Internet access. This growing demand for connectivity has been resolved, for example, by increasing the bandwidth available between buildings or improving the internal communications infrastructure itself. However, this approach is not enough to meet the new and complex connectivity needs in a Smart and Sustainable City.

Different factors such as technological evolution, the deregulation of the communications market in many countries, the explosion of digital traffic, new mobility services and the massive irruption of low-cost connected devices have created a demand for connectivity that requires specific treatment, but under a global perspective.

The number of connected IoT, machine-type communications (MTC) is expected to exceed 27 billion by 2025,[25] impacting almost every aspect of daily life. *Figure 11* shows how IoT traffic will be dominant in networks, with growth curves above 22 per cent, in contrast to HTC traffic with a practically flat growth forecast. This trend clearly demonstrates the need to face not only the challenge of how to connect heterogeneous devices to a common infrastructure but also the use of public space for the installation and power supply of these elements.

In this sense, the characterisation of these new traffic profiles requires a significant effort on the part of international standardization organizations to adapt telecommunications networks. ITU-T Study Group 20 addresses the requirements of IoT technologies by developing standards that leverage IoT technologies to address urban development challenges. A central part of this study is the standardisation of end-to-end architectures for IoT and mechanisms for interoperability of applications and datasets.

Figure 11: Evolution of connected IoT devices (estimate 2025)



Note: IoT Connections do not include any computers, laptops, fixed phones, cellphones or tablets. Counted are active nodes/devices or gateways that concentrate the end-sensors, not every sensor/actuator. Simple one-directional communications technology not considered (e.g., RFID, NFC). Wired includes ethernet and fieldbuses (e.g., connected industrial PLCs or 1/0 modules). Cellular includes 2G, 3G, and 4G. LPWAN includes unlicensed and licensed low-power networks. WPAN includes Bluetooth, Zigbee, Z-Wave, or similar. WLAN includes Wi-Fi and related protocols. WNAN includes non-short-range mesh, such as Wi-SUN. Other includes satellite and unclassified proprietary networks with any range.
Source: IoT Analytics Research, 2022 https://iot-analytics.com/number-connected-iot-devices/

For the development of a city communications infrastructure, it is necessary to jointly analyse the ecosystem formed by a large number of elements and devices (people, infrastructures, sensors-actuators) of heterogeneous characteristics that generate data flows of a very diverse nature and by the network itself that provides the necessary connectivity with quality, security and availability at minimum costs. Aspects such as geographical coverage, energy consumption and the cost of devices are variables that need to be considered.

This ecosystem is dynamic and highly unpredictable as the needs for quality, bandwidth and availability grow and vary spatially and temporally. Different areas in the city, financial as well as residential, show very different patterns of behaviour and great variability throughout the day. In addition, critical information must be available and must take precedence over less relevant information.[26] Ensuring that the network is able to adapt to the – in many cases abrupt – increases in traffic while maintaining the efficiency and quality of the underlying services is a complex task and one that entails a significant impact on costs.

The Next Generation Network (NGN) has been defined to respond to these demands. Unlike classic telecommunications networks, services and applications of a very different nature share resources of a common infrastructure. In NGN, different levels have been defined in turn, and these are described briefly below:[27,28]

- The access network allows connectivity between devices/capillary networks to a node of the transport network. It is the most onerous component of the architecture, given the huge number of users and the underlying hedging/cost difficulties.
- Transport networks provide connectivity between different access networks and are characterized by offering high transmission capacities over long distances.
- The media layer is the common core of information routing and is specialized in the dynamic management of the capabilities of the transport network, in order to differentiate traffic of different natures, adapt speeds and maintain the quality of service.
- The telecommunication services layer provides advanced communication services such as unified communications, virtual private network (VPN) services and software-defined networks (SDN).

One of the implications of a unified architecture is that the availability of network resources can change dynamically over time, and congestion occurs degrading the quality of service (QoS) compromised in international recommendations. Networks with opportunistic connections such as mobile networks or ad hoc networks are especially vulnerable to these changes.[29,30]

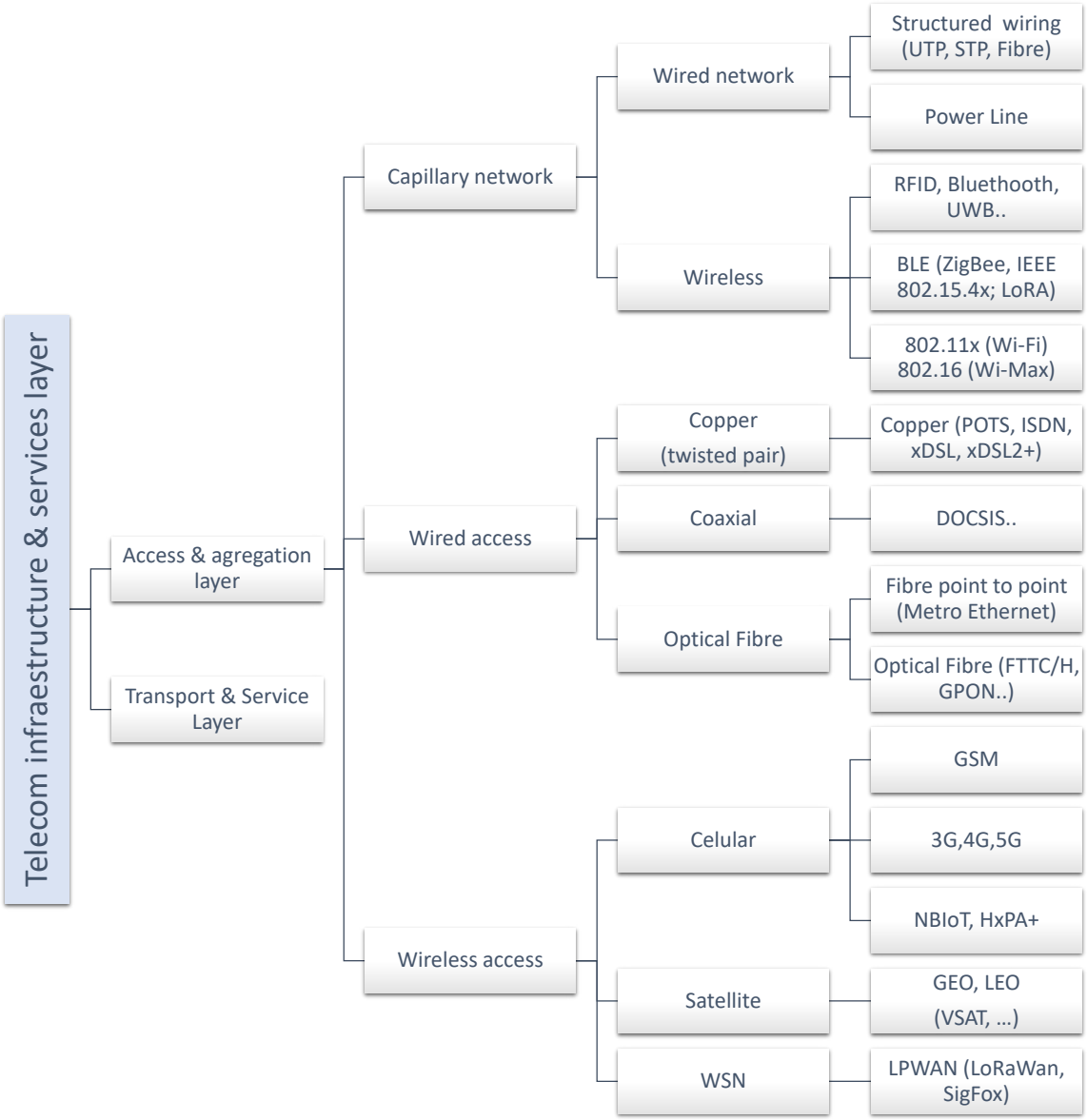
The categorisation and standardisation of this type of traffic is an area in constant development. 3GPP in TS 22.368[31] defines categories and functionalities of Machine-Type Communications (MTC) fonts, but not their behaviour pattern. ITU-T, in its Recommendation Q.3925, defines different types of sources for the verification of quality-of-service parameters in NGN, but of the seven types of MTC sources described, it leaves three for further studies.[32]

Describing in greater detail the possible technologies that may be used in the access network, as well as the rest of the planes of the NGN communications architecture, transport network and service planes[33] is beyond the scope of this document. *Figure 12* describes a high-level taxonomy of the access network so that the interested reader or municipal manager can identify the main technologies available to interconnect devices and terminals with telecommunication networks. In this sense, the capillary network has been defined to include a set of physical and logical resources that allow the connection of devices with one another and/or with another resource (Gateway) that consolidates the data of the devices and acts as a gateway with the network. The wired network enables the direct connection of the devices with the communications network. And finally, the wireless network performs functions similar to the wired network but makes use of the electromagnetic spectrum.

Although a high-level taxonomy of the access network makes it possible to identify the different technologies available to establish the HTC and MTC relationships, the choice of one or the other technology will largely depend on different aspects such as investment capability and socio-economic context.

- Coverage offered by fixed and mobile telecommunications operators.
- Deployment costs, recurring operating costs.
- Device requirements: bandwidth, traffic profile, power consumption.
- Type of service: real-time (mission-critical), uni/bidirectional, availability, reliability.
- Security and privacy.

Figure 12: High-level access network taxonomy



5.2 Connectivity Scenarios and Telecommunication Services

In this scenario of "Smart Cities and the Internet of Everything" in continuous technological evolution, municipal managers face new and complex decisions to respond to poorly defined demands that entail long-term investments and possible hidden costs of operation, administration and maintenance.

The municipal communications network, understood as the set of municipal telecommunication resources necessary for the performance of municipal functions, has been in many cases managed in a siloed model. It is not unusual for a local corporation to have a heterogeneous network based

on multiple technologies and operated by different actors such as communications operators or external companies, or through the municipal services themselves, typically specific networks for mobility, lighting, administration, and so on. Additionally, external companies that provide different services such as, for example, waste collection have communications solutions managed outside the municipal communications network.

Historically, landline and mobile telephony services, together with private municipal telephony (PABX), have been managed by infrastructure departments. However, data services such as Internet access or building interconnection have been managed by IT departments. Finally, departmental business applications have resorted to specific telecommunication solutions isolated from the municipal network. The communications network that manages the traffic light system may be different from that which manages public lighting, irrigation or environmental quality. In addition, each of them can use different technologies and has exclusive operation, administration and maintenance resources.

This fragmented scenario also represents an important brake on normal municipal technological development and the deployment of transversal solutions where networks managed by different departments are used. For example, the migration of PABXs to IP telephony or the implementation of unified communications solutions require, in many cases, an updating of the underlying data infrastructure in order to ensure the necessary speed, delay and jitter parameters. An interdepartmental project of these characteristics is complex to manage, prevents synergies, causes excessive delays in the resolution of incidents and breakdowns because its resolution falls on different departments.

In public tenders managed autonomously by municipal departments, it is not unusual for complete business solutions, including the supply and commissioning of IoT devices, to be required in order to ensure the proper functioning of the end-to-end solution. In many cases, the cost of the IoT device is relevant in the project, and this can lead to the communications technology chosen depending on the selection of the devices and not the other way around. Poor technical qualification in telecommunications, the selection of immature technologies, and the use of unlicensed bands reserved for industrial, scientific, and medical (ISM) purposes other than telecommunications, or shared technologies, can pose serious problems of compatibility, communications quality or security.

Last but not least, this inhomogeneous design of the network prevents the design of effective resilience mechanisms that guarantee the operation of municipal services in crisis situations.

Therefore, the improvement of urban public services requires a user-centric communications network offering advanced and personalized services at any time and place, a unified infrastructure that enables synergies to be obtained, guarantees harmonious growth, and facilitates the integration of new devices. Finally, and of equal importance, unified planning and management that puts the focus on users and additionally meets departmental needs.

Under this user-centric vision, the deployment of interconnected physical devices that allow the monitoring, management and processing of data has specific appliances for the tourist understood as another user of the city. Sensorization makes it possible to measure and analyse their behaviour and consumption patterns, and the real time occupancy of the main points of tourist interest. From this valuable knowledge, administrations can design accurate actions aimed at improving the management of assets with a tourism nature, influencing the flow of tourists in order to avoid pressures over the urban space (saturation) and the residents, and adjusting tourism flows to the capacity of public services the capacity of public services to the occupation conditions.

A technological vision understood as the resources available to serve the layer of users and devices is insufficient to help the municipal managers involved in the design and development of the SSC in their task of planning the necessary telecommunication services in the medium and long term.

The concept of "*Municipal Corporate Network*", understood as the management of communications assets and resources to solve municipal operational needs, allows defining infrastructures based on utility for people and processes, in a complementary way to the technologies described above.

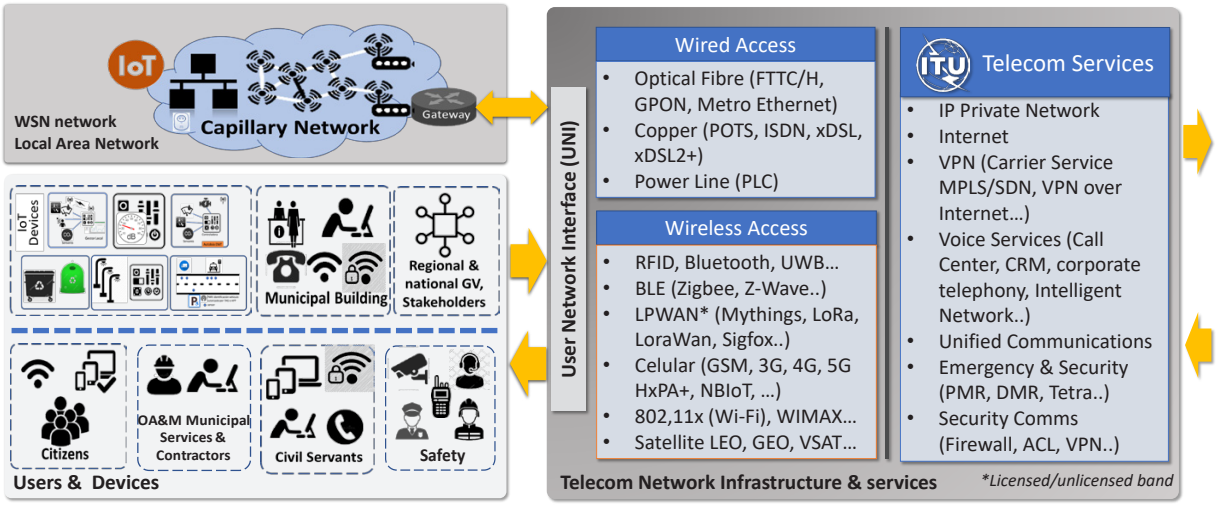
For example, municipal employees need advanced communication tools to improve productivity in the workplace and on the move. The City Council itself needs to offer mechanisms for relations with citizens through different channels, manage the IoT devices deployed or provide security and emergency services with reliable and secure communications.

A high-level approach to the resolution of the challenges previously posed for the municipal network can be developed around three lines of action:

1. ***People – Human Type Communications (HTC)***: Through the definition of standardized scenarios of connectivity and services for the different groups of the municipal organization, citizens, collaborating companies and external agents.
2. ***Processes – Machine Type Communications (MTC)***: Standardized scenarios of IoT device connectivity and data exchange between systems.
3. ***Municipal Corporate Network (MCN)***: These are the underlying communications infrastructures that support the connectivity of people and processes. They can be internal in municipal buildings or in the urban environment, provided by operators or built by the City Council itself using municipally owned resources such as ducts and optical fibre for the interconnection of buildings.

Figure 13 describes an overall connectivity scenario built upon the relationship of users and devices to the underlying telecommunication infrastructures and services. This approach enables the definition, through profiles and use cases, of the connectivity and service needs of the different municipal actors, the key aspects being the definition of telecommunication infrastructures and the response to the specific needs of the defined profiles.

Figure 13: Users, devices, telecom infrastructure & services



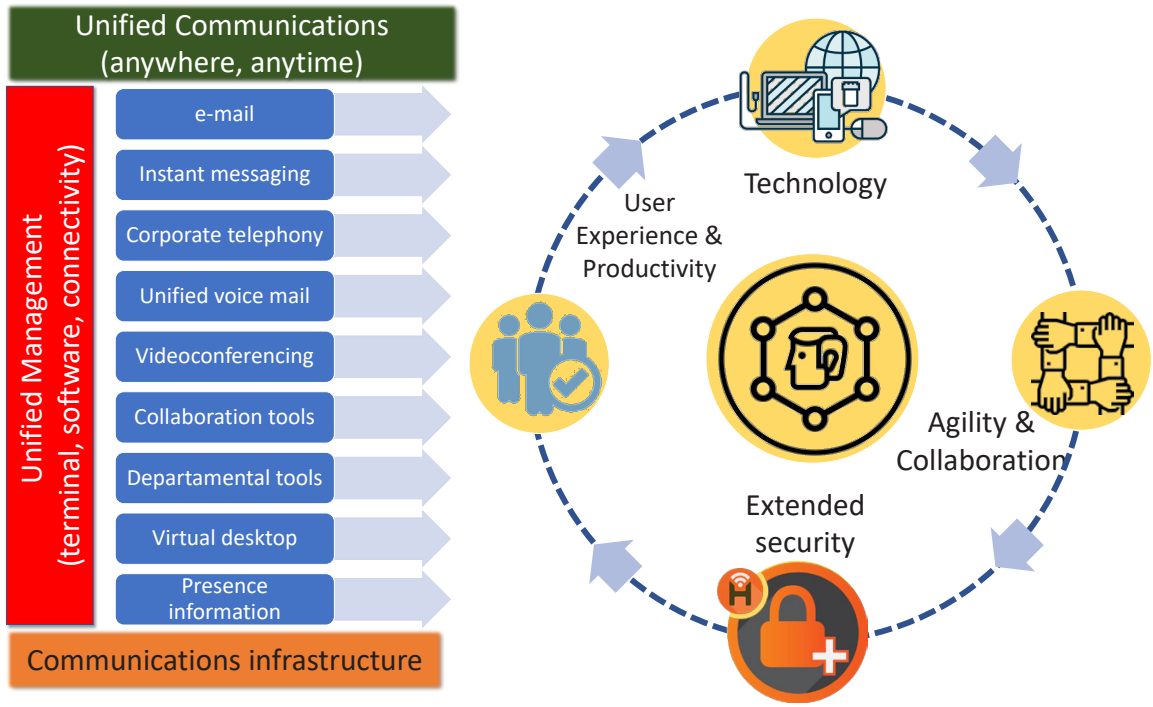
5.3 People – Human Type Communications

Human Type Communications, also called Personal communications (HTC) seek to facilitate interpersonal communication by offering integrated communication and collaboration resources through different devices (fixed and mobile) to users regardless of their physical location and workplace, in order to improve the efficiency of their daily activity and facilitate their relationship with other actors and with citizens. The most common elements are specific terminals, connectivity, e-mail, instant messaging, corporate telephony, videoconferencing, and access to departmental applications.

These communications and collaborations need for the different municipal profiles can be solved through an aggregation of heterogeneous applications or,[34,35,36] through ad hoc solutions called "*Unified Communications and Collaboration (UC&C)*".

In summary, UC&C tools integrate into a homogeneous environment the services and applications that officials may need in order to carry out their daily activities in their workplace, regardless of their physical location: e-mail, instant messaging, corporate telephony, unified voicemail, videoconferencing, collaboration tools, access to departmental applications, virtual desktop, presence status, and so on, as shown in *Figure 14*.

Figure 14: Unified Communications paradigm



This integration enables synergies to be obtained, user experience to be improved, and allows innovative services that are of value to the user to be developed quickly, thus providing a better user experience. Examples would include synchronising telephony and mail services to allow automatic forwarding of phone calls to unified voicemail during a scheduled meeting in the agenda; the conversion of telephone messages into text and sending them by e-mail or instant messaging; or the intelligent routing of calls depending on the location.

However, user mobility is associated with the need for comprehensive security and management due to the additional vulnerability produced by the need for shared media, open networks (Internet), or even malware on the device itself if the user owns it.

In the face of crises such as COVID-19,[37] UC&C has become an essential tool to promote mobility and collaboration and guarantee the continuity of the municipal operation. There is no doubt that the pandemic has had a profound effect on the very conception of municipal activity, but it has also created the urgent need to adapt the municipal corporate network to the requirements imposed by this type of solution.

This necessary upgrade requires the migration of legacy solutions to UC&C and the definition of a standardized workstation based on predefined profiles. This job can include, depending on the specific needs:

- Typology of terminals and physical devices (e.g., telephone, smartphone, tablet, personal computer).
- Connectivity with guarantees of availability and a minimum bandwidth. This would basically include a fixed Ethernet connection, access to the municipal Wi-Fi network, and access to mobile networks through VPN access.
- Base software (e.g., operating system, office applications such as text editor, spreadsheet, browsers, departmental specific software….)
- Specific unified communications applications.
- Anti-virus, anti-malware security, security of networks and municipal information systems and remote access.
- Departmental applications.

Figure 13 defines four user profiles for illustrative purposes based on the activities they develop: officials, security and protection services, citizens, and external contractors.

For example, the profile of a hypothetical municipal official in mobility and companies that run different municipal contracts, a possible catalogue of communication services, and added value for the standardized job in mobility is shown in *Table 1*.

The aggregation of this demand (number of users by profile) will impact on the connectivity resources necessary to guarantee an adequate quality of service in the day-to-day operations.

Table 1: Example of Profiles for civil servants and external contractors

Equipment & software	Civil Servants	External contractors	Connectivity	Civil Servants	External contractors
Fixed line (land line)	√	√	**Ethernet Cat. x**	1Gb/s	
Additional Services	√		**Wi-Fi (private)**	√	
Softphone	√		**City Wi-Fi (public)**	√	√
Smartphone	√		**4G**	√	
Corporate Apps.	√	√	**5G**	√	
Tablet Wi-Fi	√		**Internet**	100 Mb/s	
Tablet Wi-Fi+ 4/5G	√		**VPN**	√	
Corporate Apps.	√	√	**VPN over Internet**	√	√

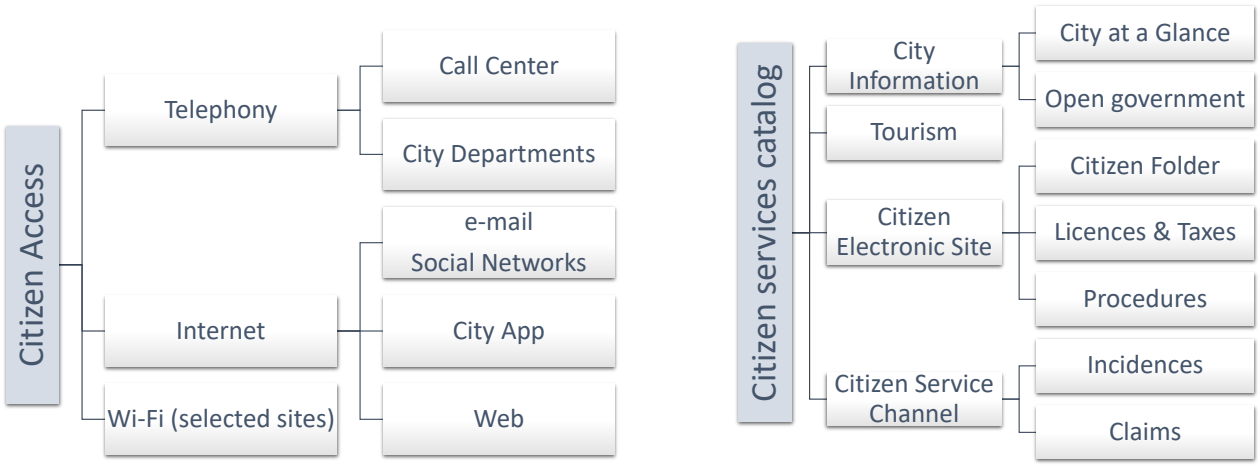
Table 1: Example of Profiles for civil servants and external contractors (continued)

Equipment & software	Civil Servants	External contractors	Connectivity	Civil Servants	External contractors
PC	√				
Corporate Software – Intranet & extranet	√	√			
UC&C for PC, Tablet & Smartphone	√				

In the same way that a catalogue for civil servants has been outlined, a model of the citizen's relationship with the City Council could be defined. This should allow the use of as many technologies as possible using the classic telephone or Internet networks. *Figure 15* describes telephone communication, e-mail, the website, the municipal app for mobile phones and tablets or social networks.

In addition to the use of telephone networks and Internet by the citizen, the City Council could offer free high-speed Wi-Fi access in municipal buildings and selected urban areas such as parks, youth centres, municipal libraries and senior centres, and could facilitate telematic access to municipal services, which (in a very summarized form) are also described in *Figure 15*. In this way, without the need to have an Internet connection, citizens could carry out procedures with the City Council itself and visit certain institutional URLs through their terminal. Depending on the specific legislation of each country, the municipality could include Internet access subject to certain conditions such as the need for registration, limited bandwidth, or even exclusive access to certain institutional URLs.

Figure 15: Citizen access to city services & Citizen Services catalogue



5.4 Processes – Machine to Machine communications (MTC)

Unlike HTC communications, this type of communication, also called M2M (Machine to Machine), covers the communication of data between entities that do not necessarily require human intervention. HTC traffic, mainly generated by IoT devices, presents very different patterns from traditional traffic patterns and is experiencing significant growth, and as a result, will probably become the dominant traffic on the network.

This section also includes traffic derived from the interconnection between information systems, access to databases, file transfer, among others.

Telecommunication networks, especially cellular networks, were designed for a limited number of users with homogeneous characteristics; consequently, the support of a large number of devices with heterogeneous requirements represents an important challenge in multiple aspects of the network architecture itself such as signalling, the nature of traffic, classes of service or the number of devices per cell.

As general characteristics of MTC traffic, we can highlight:

- A large number of devices.
- Traffic patterns with a low duty cycle, i.e., a long period between two transmissions.
- The number of packets transmitted per device is “low”, and their size is “small”.
- The traffic pattern of the devices shows small variations.
- The traffic generated by the devices is usually asymmetric, with the uplink higher than the downlink.
- There are different types of service (best effort and real time).
- A device can contain traffic from multiple sources (aggregated packets).
- Device traffic can be coordinated by application requirements.

Together with these characteristics related to the nature of the traffic, its behaviour has been classified for purposes of modelling the traffic and guaranteeing an adequate level of quality.

- Reduced mobility: Applies to MTC devices that do not move, move very little, or do so in a certain locality.
- Real-time (controlled): Useful for applications that allow information to be sent/received for defined periods of time. The network does not consume unnecessary signaling resources outside of these intervals.

- Non-real time: The operator can reject the communication request of a device based on different criteria and allow its connection in times of low traffic.
- Low data transmission: Devices to send or receive small amounts of data using as little signaling as possible.
- Infrequent Finished Mobile (MT): MTC devices that mainly use mobile access and where the operator can reduce the frequency of mobility management.
- MTC Monitoring: Monitor the behavior of an MTC device according to its characteristics such as loss of connectivity or communication failures.
- Secure Connection: Ensure the connection between MTC devices and MTC servers.
- Group-based MTC features: Optimized management of all MTC devices belonging to the same MTC group (control policies, IP addressing and others).

5.4.1 Urban Space Management

The accelerated implementation of heterogeneous IoT devices in public space such as environmental sensors, sound level meters, Wi-Fi access points and cameras, has been carried out in many cases without an established procedure, thus causing aesthetic problems, poor installations and difficulties in the maintenance of these devices. In addition to the rapid growth of IoT in the public space, new demands arise that need to be managed such as the deployment of 5G.

Ensuring efficient and scalable management of urban public space in the deployment of IoT devices is a task that needs to be addressed based on the definition of a minimum set of technical requirements such as the power supply of the devices their connectivity (see *Figure 5*) and certain guidelines to rationalize the maintenance of this new infrastructure. The nature of these devices requires, in many cases, the realization of investments, sometimes high, for their installation in specific locations and highly specialized personnel in maintenance activities.

Figure 16: Street IoT devices

To guarantee a harmonious deployment of devices in the public space of a city, at least four points should be considered:

- Define the minimum characteristics that IoT devices must meet for their installation on public roads such as protection against weathering, aesthetics, and protection against theft and unauthorized access.
- Define a procedure for the installation of IoT devices on public roads that contemplates the location of the devices, the supply of energy necessary for their operation, connectivity, and installation in an urban environment.
- Have the cooperation of the different services that manage the municipal infrastructures that can be used for the deployment of IoT devices.
- A standardized process of operation, management and maintenance of IoT devices.

Depending on the legislation of each country, the infrastructures of the urban space of municipal ownership may or may not be susceptible to use by third parties for the deployment of their own networks and devices, for example, authorized telecommunications operators. Also, the use of privately owned infrastructures capable of hosting IoT devices may be subject to certain types of regulation.

The urban space capable of hosting IoT devices is composed of infrastructures owned by the municipality and others that are privately owned. For historical reasons, and in general terms, the

different management services manage infrastructures exclusive to their area of responsibility. Despite not being an efficient solution in terms of infrastructure use due to the duplications that this entails, it has been especially valid for certain critical services such as public lighting, traffic management or citizen security.

In general, and not exhaustively, the infrastructure available for the deployment of IoT devices is described below:

- Municipal Network of Public Lighting is composed of control panels, streetlights with their supports and the corresponding pipes.
- The Municipal Network of the Mobility Service is composed of cabinets for traffic regulators, supports, and the corresponding ducts.
- Municipal Corporate Telecommunications Network (if any) for the interconnection of municipal buildings or facilities.
- Municipal buildings, including roofs and facades.
- Urban furniture (canopies, totems, etc.) that can be used as accommodation or support for different IoT equipment. At this point, a distinction can be made between municipally owned furniture and furniture with advertising support under the regime of exploitation by third parties, in which case it could be subject to certain technical and/or exploitation limitations.
- Other elements of a public or private nature capable of hosting IoT devices.

However, for the deployment of IoT devices, it is necessary that the entire available infrastructure can be used independently of the management service. This is particularly important in order to achieve substantial savings in installation. For example, the installation of a sound level meter in a given location entails an associated cost of installation, power and connectivity that can be very variable depending on the civil works necessary to install power and connect this equipment to the network.

In this sense, *Figure 17* describes a high-level grouping of the different elements to be considered in the installation of IoT devices in municipal public space, grouping municipal assets by category and not by the responsibility of the management department. The control centres or control panels are cabinets distributed throughout the city that house the necessary equipment for the realisation of different functions such as the control of groups of traffic lights and the control of the lighting of an area.

Figure 17: IoT Device installation taxonomy

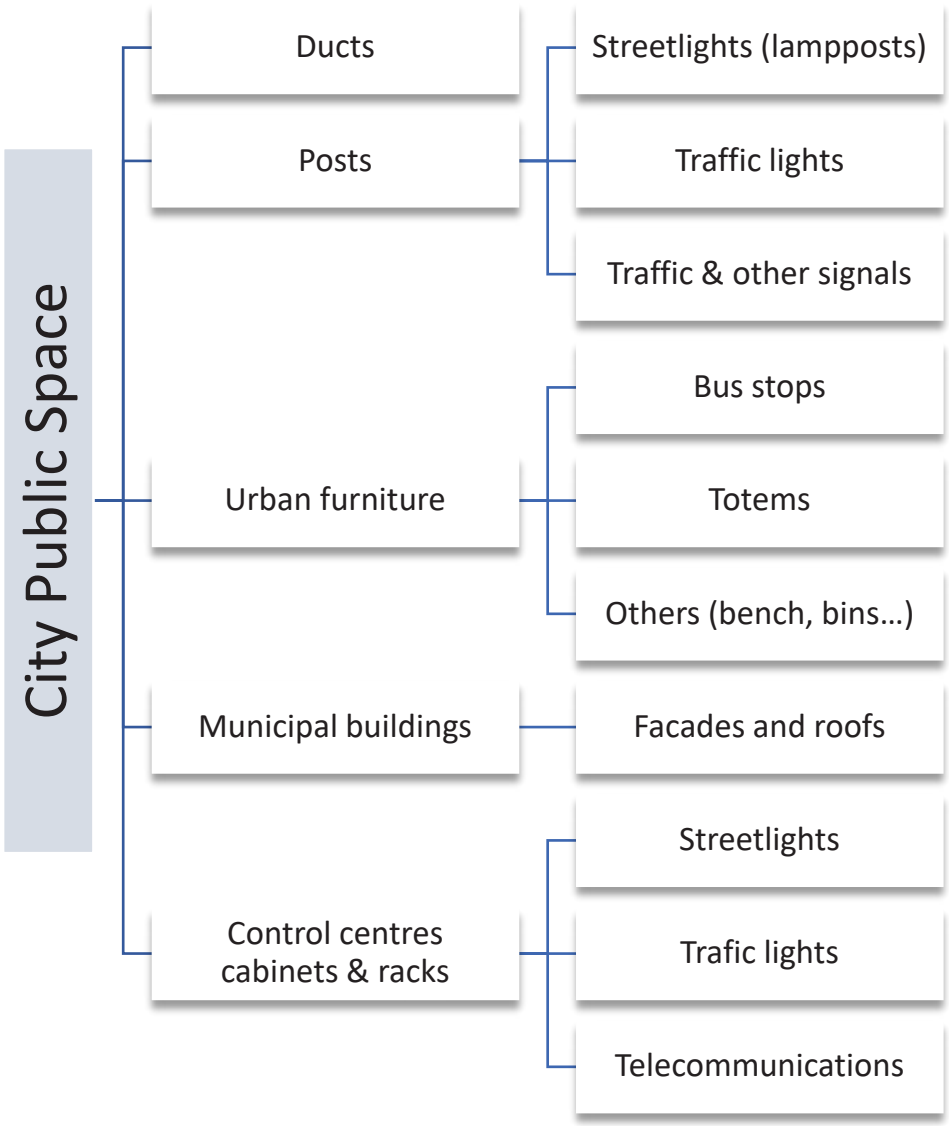


Figure 18: Street Control Centre

The first aspect to consider is that IoT devices must be installed in such a way as to minimize the visual and environmental impact and must be installed under the supervision of the department, if any, in charge of the management of the Municipal Public Domain. This applies to the installation, size, typography and colours of the different devices and anchors to align them with the aesthetics of the city.

Before the start of any installation, it is convenient to elaborate an implementation plan, which will be adapted according to the characteristics of each IoT project. This implementation plan must be approved by the municipal departments involved and must guarantee that the services that were currently being provided and could be affected as a result of the installation work to be undertaken are carried out in periods of scheduled stops that are established in agreement with the municipal technicians. In the case of civil works requirements, the design, layout and type of channelling must be coordinated with the departments involved before the start of the works and must be supported by a work project that guarantees adequate registration in the municipal systems.

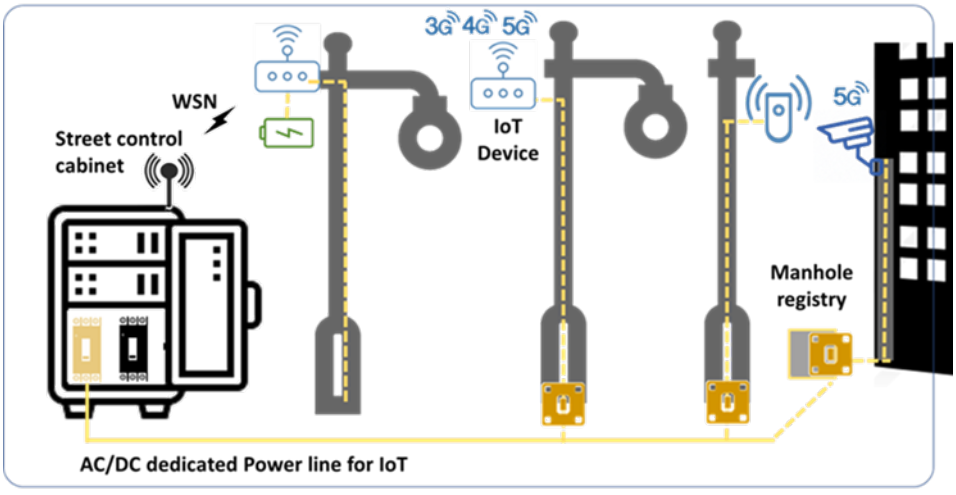
IoT devices must be made of a resistant material capable of withstanding vandalism. They must also be able to withstand adverse weather conditions by complying with an IP 64 degree of protection. Their specific characteristics will be defined in each of the IoT projects to be implemented due to the heterogeneity and specific characteristics of IoT devices.

Different types of support may be used: specific supports, lighting, staffs, facades, roofs or street furniture as described in a non-exhaustive manner in *Figure 17*. The installation of IoT devices on supports managed by a municipal department will be carried out with the prior knowledge and acceptance of the affected management department (mobility, lighting, etc.). In any case, they can be installed at a sufficient height (more than 3 metres) to prevent theft and vandalism.

The power supply for IoT devices should, as far as possible, be designed to minimize running costs of maintenance battery replacement and to support low-carbon environmental solutions.

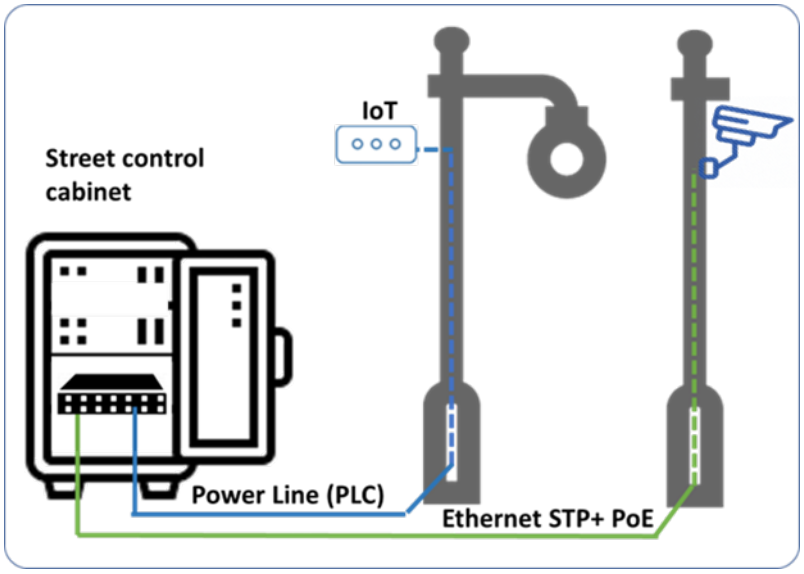
- In general, devices that require a continuous power supply will use the energy of the specific holder itself, if available. To provide protection and to be able to operate on each individual IoT device, a high-sensitivity differential circuit breaker or a fuse will be installed in order to, in case of breakdown or maintenance of the device, operate on it without affecting the rest of the system.
- Devices that require a continuous power supply and whose holder does not have power will be connected to the nearest command centre using the existing ducts of the public lighting network or the mobility department, as shown in *Figure 19*. The choice of infrastructure will depend on the relative location of the IoT devices with respect to the frames and the costs of civil works. To ensure security and non-interference with existing services, the power supply system for IoT devices will be protected by a differential circuit breaker or a fuse on the dashboard to protect the set of IoT devices that are installed. This power line should be independent and should not be shared with any other service. The characteristics of the cable, section, cover, etc., will depend on the applicable regulations in each country.
- To protect and be able to operate on each individual IoT device, it is recommended to install a high-sensitivity differential thermal magnet switch or a fuse with sufficient characteristics in each of the poles or connections where the IoT device is installed. In case of breakdown or maintenance of the device, it must be possible to operate on it without affecting the rest of the system.
- In the specific case of public lighting, there are some particularities to consider. In standard installations, the lighting poles have energy only the moment the streetlight line is activated. Using a battery of sufficient capacity, the IoT device could remain active during periods when the line does not have power.

Figure 19: Power Supply for IoT devices with wireless connectivity



- Where the connection of the IoT device to the corporate network is made by Ethernet cable, it can be powered using PoE (Power over Ethernet), using an RJ-45 STP cable from the nearest controller, as long as the technical specification of distance allows it.
- Where the connection of the IoT device to the corporate network is made by PLC[38] technology, the power will be obtained from the supply line itself.
- Where any of the above options are not viable for cost or operational reasons, the power of IoT devices can be provided by batteries and solar panels.

Figure 20: Power Supply IoT devices with Ethernet or PLC connectivity



In addition to the complexity of the physical installation of IoT devices in public space, connectivity is the key factor in ensuring the correct functioning of the solution.

The connectivity system shall meet the requirements of:

- **Availability:** The network must meet the quality-of-service objectives set out in international recommendations in terms of coverage, delays and packet losses.
- **Security:** IoT devices, due to their installation, in many cases not attended, are elements susceptible not only to be stolen but can be attacked in order to make malicious use of them. The information generated by IoT devices, in many cases, is confidential and subject to different data protection legislation.

The connectivity of the devices must be carried out in such a way as to avoid, as far as possible, shared media and by making use of secure protocols for the transmission of information, thus allowing its remote configuration and the update of the firmware of the device. The security architecture will define the hardware, software, protocols, and policies to create the environment

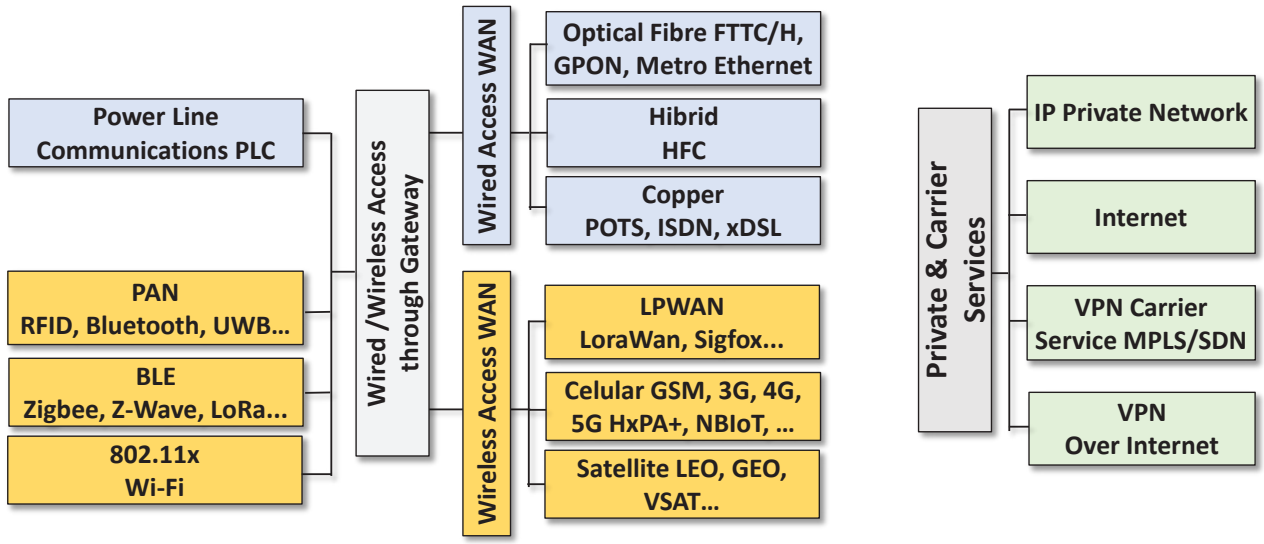
on which the components object of the different IoT projects work reliably, securely and with high availability. It shall cover at least:

- Authentication and authorization.
- Security in communications and security of all the elements deployed in the different components, especially the sensing layer.
- Monitoring and integrity of the system.

The use of one or another technology, as noted in previous sections, will depend on different factors such as the need for bandwidth, the existence of a municipal corporate network, the coverage of operators, and costs.

Figure 21 describes, in a more summarized form, the main connectivity alternatives and associated services:

Figure 21: IoT Access technologies



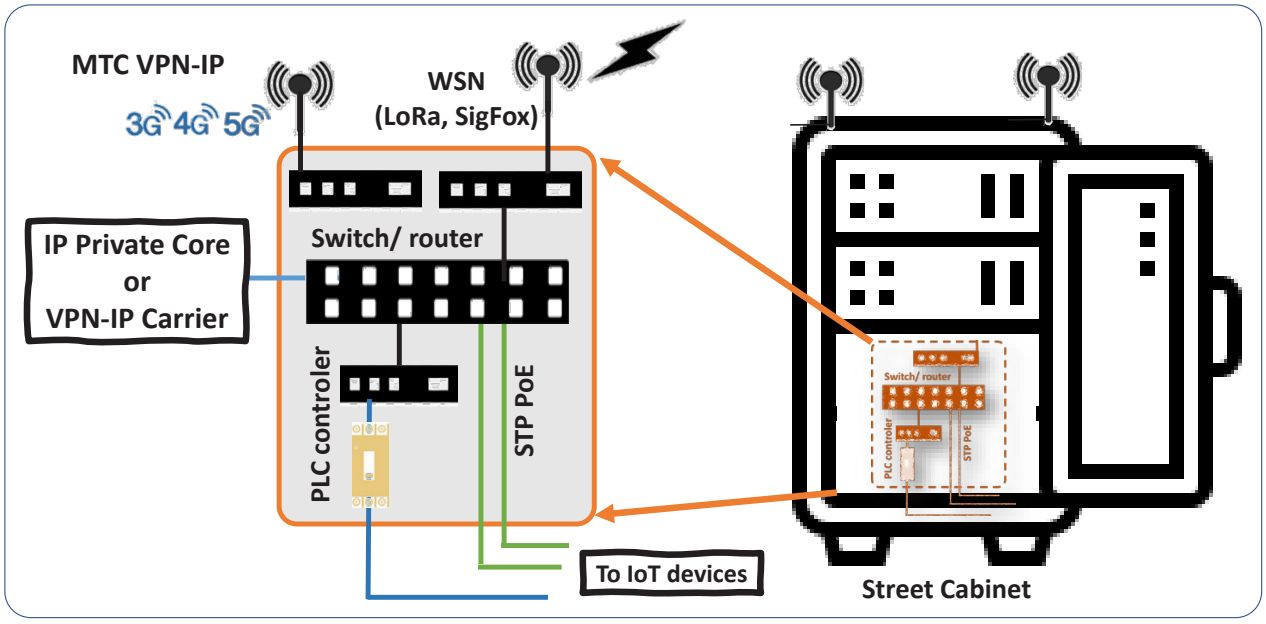
Wired connections are required for devices that require high bandwidth and/or where cellular technology is not available. This would be the case of cameras deployed to reinforce citizen security or traffic management.

As noted in previous paragraphs, access to the municipal corporate network can be through the nearest lighting command or traffic light management centres that have connectivity. It will be necessary to analyse the type of connectivity available in order to adapt it to the integration needs of the device.

Figure 22 shows the equipment that could be installed in a non-exclusive way in the previously referenced cabinets.

- Connectivity with IoT devices that use WSN protocols will be done through a gateway installed in the cabinet.
- Connectivity with IoT devices using PLC protocols will be done through the PLC controller installed in the cabinet.
- Connectivity with IoT devices that use STP cabling with PoE will be done through a switch preferably with industrial characteristics.

Figure 22: Connectivity IoT Ethernet



Connectivity with the municipal corporate network may be carried out through the municipal connectivity infrastructure itself if it exists, or by contracting fixed and mobile VPN services to a telecommunications operator. Finally, there is also the option to create a VPN connection over the Internet.

5.5 City Corporate Network

The City Corporate Network aims to deploy a unified set of advanced telecommunication services for the municipal community under a unified management, and to reduce overall costs in communications. It includes not only connectivity resources but also the hardware and software elements that support the relationship models of people and processes described in previous sections. Its nature and geographical scope cover the municipal and urban environment. They may

use proprietary infrastructure or resources provided by third parties such as virtual private network services and applications, private or public cloud services, or the Internet.

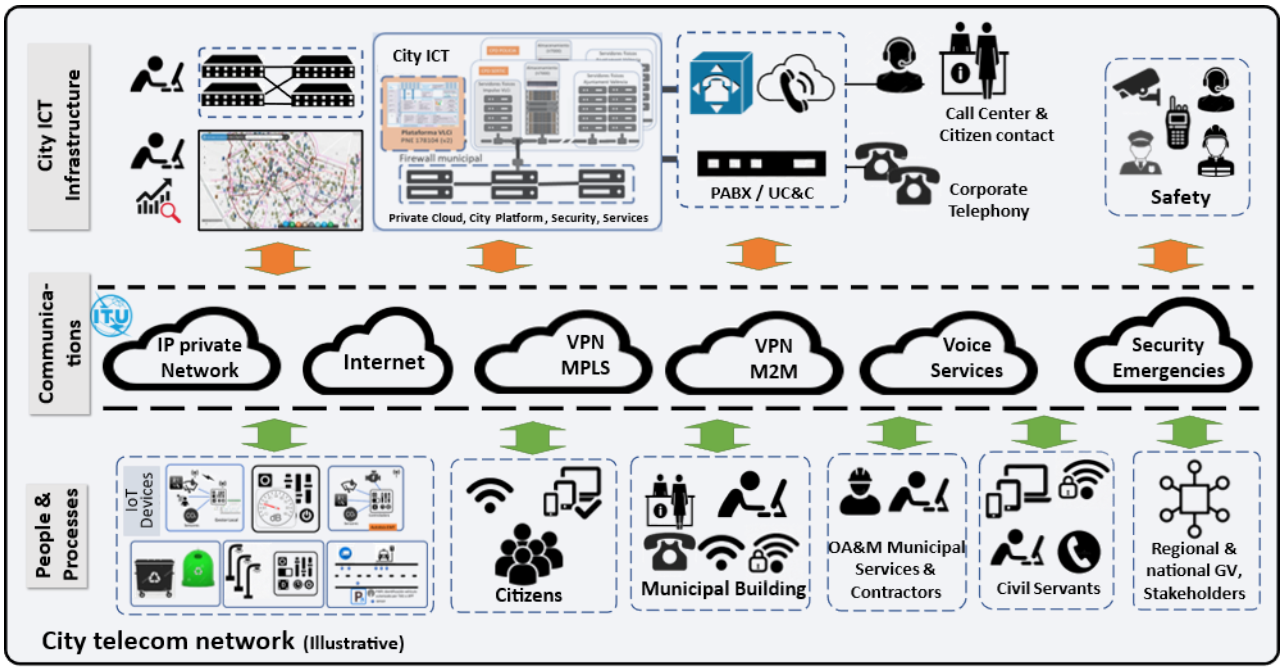
Under this concept of infrastructure, services and common applications for municipal activity are grouped:

- The communications infrastructures that allow people, and buildings, to interconnect with each other.
- The infrastructures that allow the access and exchange of secure information with third parties such as citizens, collaborating companies and other entities.
- The ICT infrastructures that host different services such as corporate telephony, the multichannel citizen service center (contact center), the municipal intranet, or corporate application servers.
- Specific applications are necessary to carry out the functions described above such as unified and collaborative communications, intelligent network services provided by telephone operators, and so on.

Figure 23 conceptually describes the different functional blocks and profiles described in the people and processes sections. On them is shown the connectivity provided by the different technological solutions: dedicated infrastructure, Internet, virtual private network service provided by the operator of fixed and mobile connectivity, voice services and, finally, networks dedicated to emergency and security services (PMR) that can, in turn, be provided through infrastructure and resources owned by the municipality or by a specialized operator.

On the communications layer, the ICT infrastructure layer consists of the specific communications equipment and applications necessary for the development of the functions and profiles of the lower level. Examples of elements of this infrastructure could be the local area networks of corporate buildings (e.g., structured cabling, switches, routers, access points), computer and storage hardware, application server base software, and citizen service software (contact center / CRM).

Figure 23: Smart City relationship between City ICT infrastructure, communications, and people & process

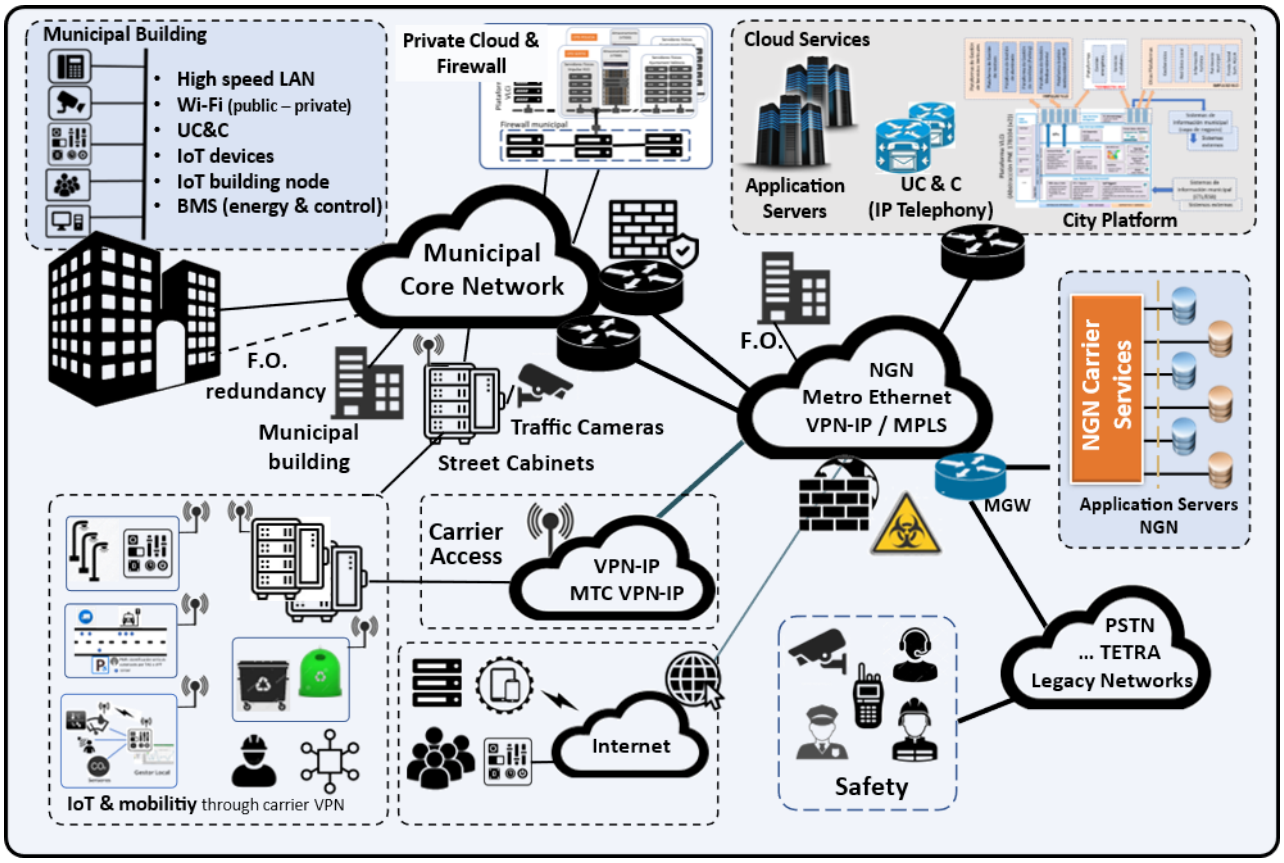


In the previous figure, a scenario applicable to a generic local corporation has been described; however, aspects such as telecommunications legislation, geographical dispersion or the availability of services and costs of operator services can substantially modify change the mix of technologies used substantially.

Figure 24 describes a generic communications architecture for an SSC. It has defined different functional blocks that must allow the achievement of the objectives pursued in the municipal corporate network.

- Municipal core network operated by the City Council itself using its own resources.
- Voice and VPN carrier services.
- Internet services.
- Security and emergency services.

Figure 24: Generic Smart City Communications& connectivity Architecture



5.5.1 City Core Network

The Core Network is composed of the communications infrastructure inside corporate buildings (local voice and data infrastructure), the connections between them to share municipal ITC resources and the capillary network that enables the connection of IoT devices. This can provide common services to officials regardless of their physical location, for example, telephone services, access to application servers in municipal data processing centres, access to video surveillance cameras, traffic light control systems, public lighting controller centres, and more.

The interconnection between buildings generally requires high bandwidth and protection mechanisms in case of failure for those buildings of critical availability. This interconnection network can be offered in service mode by telecommunication operators through fibre-optic interconnections; for example, ITU-T G.709[39]or by using technologies based on Metro-Ethernet standards[40] or GPON[41] that provide added value to connectivity such as automatic protection against link failure, quality of service guarantees and centralized management.

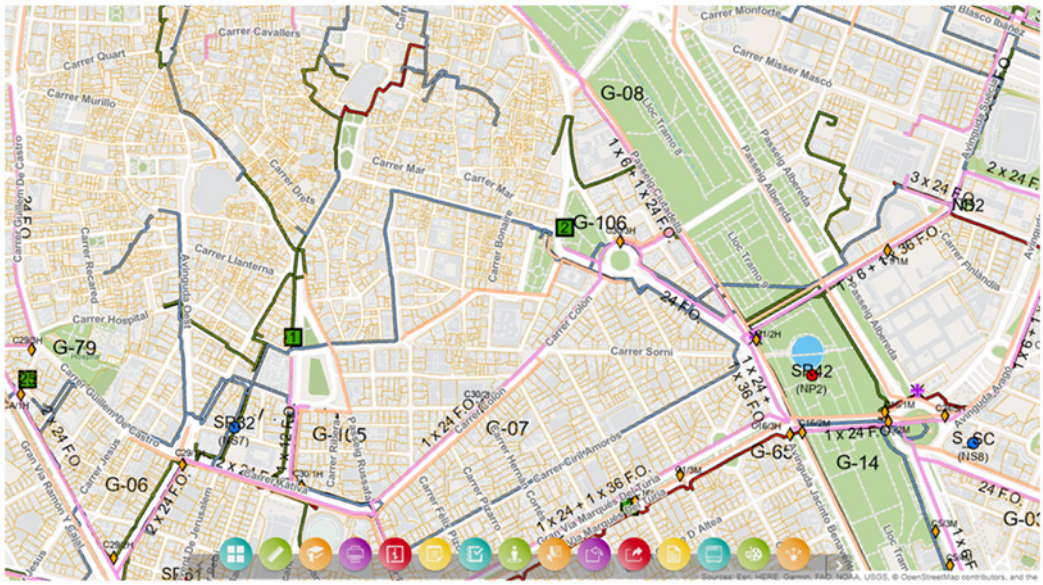
Alternatively, and for strategic or cost reasons, cities can build their own network of the interconnection of buildings at a very competitive cost compared with other available options since they have

infrastructures that can be used for the deployment of telecommunication networks. Public furniture such as bus stops, the traffic light network or the lighting network are examples of this.

Alternatively, and for strategic or cost reasons, cities can build their own network of the interconnection of buildings at a very competitive cost compared with other available options since they have infrastructures that can be used for the deployment of telecommunication networks. Public furniture such as bus stops, the traffic light network or the lighting network are examples of this.

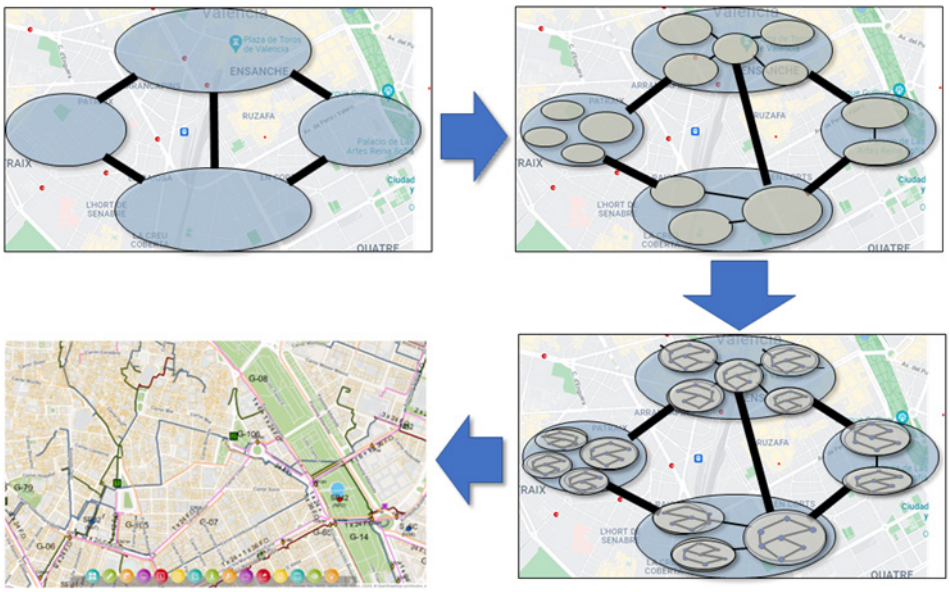
The decision to build, operate and maintain a proprietary network will depend largely on the topology (location of the buildings), the cost of investments (CAPEX) and the recurring operating costs (OPEX). *Figure 25* shows the topology of a fibre-optic network deployed in the city of Valencia (Spain).

Figure 25: City of Valencia, optical fibre core network



Finally, the private capillary network enables the access of the devices deployed in the urban environment to the municipal corporate network providing connectivity to different auxiliary infrastructures available such as the control cabinets distributed in the city already described in previous sections. *Figure 26* shows a generic example of a capillary network, the deployment of which will depend on municipal operational needs.

Figure 26: Optical fibre deployment strategy



In practice, the municipal corporate network will be constituted by proprietary infrastructure and operator services in such a way that the objectives pursued of quality and availability are achieved at minimum cost.

5.5.2 Voice and VPN Carrier Services

Communications operators offer telecommunication services that allow the municipal corporate network to be connected with the outside, as well as enabling the integration of devices, systems, switchboards (PBX), users and buildings that, for reasons of management, efficiency or costs, are not directly connected to the municipal communications infrastructure.

Depending on the country, the converged voice, and data services that operators offer may vary, as might their coverage. In general, these operator services offer fixed access based on Metro Ethernet, GPON, xDSL standards, and others, as well as mobile (e.g., 3, 4, 5G, NbIoT). In addition, they offer value-added services to connectivity, and guarantees of quality, availability and security based on redundant infrastructures and service level agreements (SLAs).

For voice communications, telecommunications operators offer fixed/mobile/UC&C voice virtual private network functionalities, as well as the integration of municipal voice communication systems. The connection to or from the outside is made through consolidated ISDN access or SIP trunking.

As an example, the Spanish operator Telefónica offers a local network interconnection service on Metro Ethernet + IP infrastructure (based on MPLS technology called Macrolan/SDN VPN-IP) that allows the creation of virtual private networks while maintaining the same benefits as a private network.[42]

IoT devices that cannot connect directly to the Private Communications Network for reasons of mobility, security or coverage generally use an MTC virtual private network service contracted from the operator. This MTC service uses 2/3/4/5G mobile networks to connect with the device and routes traffic to the municipal private network via a fixed network link based on Metro Ethernet or GPON standards.

These devices can be simple elements such as containerized fill sensors or single-layer capture gateways in an IoT architecture. An example of the latter scenario is lighting management, where different streetlight controllers are connected to each other by ZigBee or PLC type technologies and with a segment controller that, in turn, establishes a connection with the municipal corporate network through the MTC VPN service.

5.5.3 Access to services and devices via the Internet

The flexibility and coverage of the Internet is an asset of great value to the municipal corporation in its relationship with citizens, in the remote access of members of the corporation, and in the connection to external stakeholders. These accesses allow the establishment of Internet connections with guaranteed data flow to offer an adequate user experience, and for reasons of quality and availability, they are usually redundant. The connection of the town hall with the network of the Internet provider is usually made using the Metro Ethernet standard.

IoT devices that do not connect directly to the Municipal Private Network and that have few requirements for quality, security, and availability route their traffic through existing corporate Internet access. Examples of this scenario are the terminals of the collaborating companies of parking management or cleaning, urban noise meters or citizens' devices (smartphones). In these cases, the low variability of the information, and the low availability requirements, advise low-cost access.

Remote access to the municipal corporate network through the Internet is the mechanism preferred by UC&C systems for access by members of the corporation outside the office, in teleworking and for interconnection with other external agents.

5.6 Use case. UCC & IoT initiatives in the Valencia City Council

The generic municipal architecture that was shown in includes users and devices directly connected to the City Corporate Network, users and devices connected through MTC VPN-IP mobile services, users and devices connected through VPN-IP services, and users and devices connected through the Internet.

The design and implementation of a project that affects the municipal network must be planned carefully to evaluate the impact over other communications, and to identify possible network needs before their implementation in order to guarantee the overall quality of service. Simulation tools contribute with the necessary flexibility, and they can help to solve the complexity of designing a

Smart City communications network, where numerous and heterogeneous devices compete for a limited bandwidth. At this point, simulation tools can serve as a basis for the development of digital twin strategies.

There are different municipal initiatives in the Valencia City Council related with the deployment of IoT devices and the modernization of city communications infrastructures.[43] Some of them are related to urban air quality, noise monitoring, street lighting and urban waste, and a possible migration of the current telephony network based on TDM to a Unified Communications and Collaboration solution (UCC&C) with centralized servers sharing the same hosting architecture as the Smart City platform. Detailed information on selected use cases and network impact, can be found in the IEEE-Access article[44] (sections VI to VIII).

6 City IT Ecosystem

City core systems are the key elements that allow municipalities to support relationships with citizens and administrative systems.

What are the principles of digital development? How do they help in developing cities?

City platforms are based mainly on international and national standards. These standards have in common architecture based on layers, where the different capacities foreseen for a city platform are grouped.

- What are the functionalities that an Urban City platform should have?
- What layers should be present to improve the integrated management of the city? What are the enabling elements of the city's digital transformation that organizations should have?
- What interoperability problems between systems and platforms can cities face? How do you deal with interoperability between different Administrations?
- What are Building Blocks, and how can their technology help the agility and start-up of the components? What technical requirements are needed for its implementation?
- What technologies offer a guide or model to build an integrated city or government platform, taking advantage of implementing the Digital Public Goods (DPGs) model?

6.1 The IT Ecosystem

The reference technological architecture proposed in previous sections describes a long-term objective model. Like other sectors of the industry, cities are immersed in a continuous transformation of their information and communications systems to respond to the growing citizen demand for more and better public services, transparency, and good governance, all in an environment of increasing scarcity of resources.

The reality that municipalities face, in general, is that the systems on which the main administrative and municipal operational procedures are based were designed ad hoc long ago in a model based on self-contained applications, "silos", which are not very flexible and do not meet new needs, and whose adaptation requires significant economic and organizational efforts.

The pragmatic approach of many cities to this transformation has been to make legacy systems coexist with new cloud-based solutions (private, on-site or public) building an architecture based on microservices and containers. Unlike other industry sectors, public administrations have additional regulatory requirements due to the nature of the information they manage. This may limit cloud

platforms' use in regions where the legislation on data protection and management does not have the same scope.

Currently, cities have different applications to solve operational needs, normally linked to defined areas of action such as mobility, security, public lighting or waste management, which, in most cases, correspond to municipal organizational structures. There are also heterogeneous external systems such as transport services, systems linked, for example, to buildings, tourism, hotels and social networks managed by third parties.

With these premises, municipal managers must build new operating models that allow them to meet citizens' demands while incorporating all these new technologies, many of them innovative, to be more agile and efficient. This change in the organizational and cultural model described in previous sections is complex to implement because it generates uncertainties, new risks, and a political impact due to the limited, short-term visibility that these paradigm shifts provide.

This architecture has allowed the development of a flexible layer of services and applications based on Web environments and Apps such as the electronic headquarters for carrying out administrative procedures, specialized portals, social networks, communication with external actors, and the incorporation of geospatial information for asset management that connect internally with legacy systems to offer the necessary functionalities.

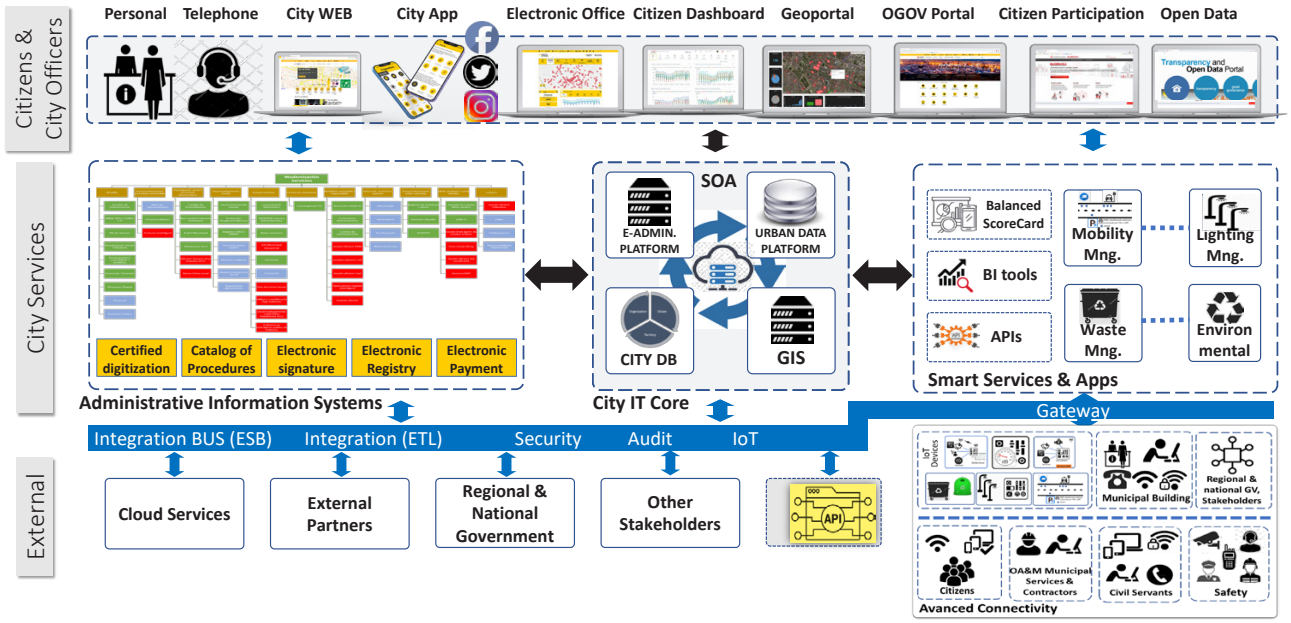
In addition to this already consolidated reality, the emergence of new paradigms such as those mentioned in previous sections: Artificial Intelligence, the Internet of Things, Big Data, Edge computing, augmented reality, and many more have led to the introduction of the "Urban City Platforms"[45] that group these new functionalities into a common frame of reference. Although there are a significant number of so-called City Platforms on the market, recommendations ITU-T Y.4201[46] and Y.4200[47] include the high-level requirements, reference architecture, and interoperability requirements to guarantee investment and compatibility with other market solutions. In later chapters, the basic functionalities provided by these platforms will be described in greater detail.

With this complex and constantly evolving scenario, the ICT ecosystem as a data infrastructure for the services of a Smart and Sustainable city would be composed of architecture such as the one described in *Chapter 1*, based on microservices together with an integration bus to facilitate the exchange of information between different systems, as well as administration tools, security mechanisms and protection against failures. In large blocks, this ecosystem would be composed of:

- Applications of value for citizens and the municipal officials themselves.
- The systems that host the applications of municipal administrative procedures, financial management, collection, etc.
- Vertical application servers: mobility systems, waste management, environmental management, lighting, etc.
- Communications infrastructure for people, buildings, IoT, and citizens.

- The IT core of the city is made up of at least:
  - The private municipal cloud is where the business applications reside.
  - Municipal databases.
  - The Geographic Information System.
  - The Urban City platform.
- Security systems, auditing, and architecture management.
- The buses and integration mechanisms of the architecture with other external systems, collaborating companies, other administrations, and stakeholders.

Figure 27: Smart ICT Ecosystem – Data infrastructure for City Services



6.2 Applications of value for citizenship

6.2.1 Electronic Office

The electronic office is a web portal available to citizens on the Internet. It is owned by a public administration in charge of managing and administering it. Citizens and companies can access information and electronic services and procedures of the administration at any time and thus save time.

The right of citizens to interact and communicate by electronic means with public administrations entails the need to define clearly an electronic administrative headquarters through which citizens

can access the information and services of the incumbent administration with the same guarantees as if they did this in person.

Therefore, the electronic office must be equipped with the legal, organizational and technical measures that guarantee that the contents and services are provided under the principles of official advertising, responsibility, quality, security, availability, accessibility, neutrality, interoperability, identification and authentication.

Ownership of the electronic headquarters will correspond to the administration of each municipality that assumes responsibility for the integrity, veracity and updating of the information and services that comprise it. The electronic offices will have systems that allow secure communications whenever necessary.

The publication of information, services, and transactions in the electronic offices will respect the principles of accessibility and use under the regulations established in this regard, open standards, and, where appropriate, those others in general use by citizens. The electronic offices will use recognized or qualified website authentication certificates or equivalent means to identify themselves and guarantee secure communication with them.

From this Platform, the electronic services that the municipality makes available to citizens should be accessed, and access to other offices and management services depending on the municipality.

6.2.2 City App

City applications provide residents and tourists with an intuitive and agile mechanism to communicate directly with City Councils, taking advantage of the great implantation of mobile devices in society.

The apps also integrate, in a single environment, all the information related to the city and are configured as an innovative means to promote citizen participation.

The services that a city app should have, are:

- Find all nearby services.
- Consult the itinerary of the bus or metro lines.
- Stay on top of all alerts and notifications.
- Carry out multiple administrative procedures without travelling, available from the City Council portal and the Municipal Electronic Headquarters.
- Access the official pages to carry out different procedures such as register certificate, tax payment, fine management, etc.
- Receive notifications when you receive messages from the Electronic Office.
- City agenda.

- Directory: locations and telephone numbers of institutions, entities or establishments of interest.
- Tourist-oriented services: cultural routes, the possibility of seeing historical monuments with Augmented Reality, audio guides for emblematic monuments, and virtual tours.

A proper city app considering tourists as users of the city, must offer them relevant content segmented according to their preferences, space-temporal location features that enrich their experience, tailored recommendations during their stay, and real-time information about the city and its assets.

6.2.3 City Dashboards

The area of the Mayor's Office of the municipalities and the municipal managers need dashboards to see the state of the city and the municipal services in order to make better decisions for the municipality's environmental and economic management and sustainability.

The dashboards must have an interface adapted to the municipal organization, integrating all kinds of resources allowing the data to be consulted in a georeferenced way using the municipal geographic system from the dashboard itself and integrated with the open data portal.

It is very useful because it facilitates the monitoring and follow-up of how public policies on the territory are being carried out.

The main advantages of municipal dashboards are:

- Improve the transparency of public management.
- Improve the productivity of public management.
- Balance public management between immediate action and preparation for the future.
- Better information for managers.
- Resource savings, time as well as financial.

The importance of dashboards is that they allow indicators to be related. Information is received on what is happening, and the cause of why it happens is known. Some indicators can be more global (view of the Mayor's Office) and more specific (view of municipal services).

As an example, regarding specific municipal services, a tourism city dashboard must consider performance indicators on behavior, preferences, interaction, tourist movements (flows), saturation, competitive performance of the destination and its digital assets, and citizen sentiment contextualized in space and time.

6.2.4 Citizen Dashboard

The creation of a "Citizen Dashboard" showing the state of the city in real time provides citizens with a resource where they can see the main metrics and indicators of interest at a glance.

Re-using the open data services of the city platforms and the services of the municipal geographic information system, the Citizen Dashboard will bring together a series of indicators and resources in real-time that enable the state of the city to be known.

Complementing these dashboards, other specific municipal services related applications, such as tourism, could also allow the collection and analysis of data from a specific geospatial context, displayed on an interface or map for the visualization of the impact of tourism on the city.

Some relevant resources to view:

- Traffic maps.
- Map of incidents and activities on public roads
- Weather forecast and state of air quality in the city.
- Status of free spaces in each car park.
- Municipal communications and incidents.
- Social networks.
- Agenda and news.

6.2.5 Citizen Attention Channel

The information and telephone service for citizens has the mission of being the gateway to the efficient satisfaction of citizen demand regarding information about the city and its services and the performance of municipal procedures.

This service tries to advance in the improvement of municipal functions by offering the possibility of carrying out procedures without the need to travel, with three strategic objectives:

- Achieve a more transparent, efficient administration that is closer to citizens.
- Achieve a high level of efficiency in resolving the demands that concern to the service.
- Improve the quality of life of citizens.

The citizen attention channels will use computer tools, whose fundamental axis is the citizen relations management system (CRM). This system must include advanced capacities such as the integration of the municipal authorities through the city platform, which will facilitate the carrying out of procedures such as obtaining proof of registration, payment and direct debit of taxes, and

requests for home telecare. The record of the result of the services and the assessment of its users, the recovery of detailed information on the service provided in the event of a claim or incident.

Such citizen relations management systems must also aim at the satisfaction of tourist demand by first generating a link between them and the destination. This bonding process, together with a specific loyalty module, is able to provoke new visits, thus increasing overall profitability from this activity.

6.2.6 Geoportal

Geographic Information Systems (GIS) enable a wide variety of existing resources to be made available to citizens of the city councils.

The SIG offers information through a map view by different municipal areas such as mobility, economy, social services, sports and public works. Users can select the information of interest through a map and choose the ones they want to view.

The GIS will allow decision makers and municipal managers to identify problems, monitor change, manage and respond to events in the city, make forecasts, and understand and establish priorities.

The GIS must include a section of plans open to the use of citizens: street map, mobility map, urban planning, tributary zones, open data, historical maps, gardening, markets, social networks, and social services.

In addition to the planning tool for administrative use, the following may be included: rates and taxes, tables and chairs, tourist apartments, incidents on public roads, lighting inventory and infrastructure works, among others.

With this tool, the administrations manage to optimize their resources and improve their digital public services, promoting government transparency and adapting their processes easily and simply.

As an example, geolocation of businesses, stores and restaurants displayed in real time on a map would make citizen and tourist mobility more efficient, since their consumption itineraries would experience an improvement. Therefore, the potential of this application encompasses not only the identification of urban problems, but the enhancement of the tourist experience and the quality of life of residents through mobility.

6.2.7 Open Data

The Open Data Portal is the digital space in which municipalities publish in open formats the data they produce as a result of the activities they carry out in the exercise of their powers.

The portal's objective is to provide citizens with free and open access to public data so that they can use and re-use these data to take advantage of their economic and social potential. At the same time, the publication of these data contributes to improving and reinforcing the transparency and accountability of the city councils.

Open data management is a global initiative linked to open government policies, which seeks to ensure that data and information, especially those held by public administrations, are published in an open, regular and re-usable way for everyone, without access restrictions, copyright, patents or other control mechanisms.

The philosophy of these initiatives is to promote transparency, efficiency, citizen participation and economic development. In addition, with a double slope:

The first part serving individual interested persons and companies so that they can use public information:

- For simple queries.
- To enrich the information with new data (give added value).
- To generate applications and services.
- To generate new business.

And on the other hand, providing greater transparency to all public administrations.

- The publication of the data held by the administrations in open formats is the optimal way to generate trust in the institutions. It exposes the work carried out in the different institutions and shows how public resources are managed and invested.
- Aid for general economic development, the generation of new sectors and services for citizens.

6.2.8 Transparency Portal

Citizens and society increasingly demand more information about the different actions carried out by public authorities; they aspire to the free use of public information in an easy and accessible way; and they seek to know what, who, how, when, and how much those responsible spend on the various policies they develop.

Today, transparency has become a fundamental indicator of the quality of governments that aspire to be considered democratic and a necessary budget so that citizens can adequately exercise their assessment and a true participatory intervention.

When the information of society increases by generalizing access to it in the power of the public sector, a better knowledge of the opportunities, circumstances, and procedures that exist is propitiated, and new perspectives are opened for decision-making.

The Charter of Fundamental Rights of the European Union, in its articles 41 and 42, recognizes the right of European citizens to good administration and free access to the documents contained in the European institutions.

The success of transparency policies depends on information being accessible and available to all users. A public policy is transparent if it is understandable, if the information is available, and access to public information is guaranteed. The protection of applicants' data is safeguarded if accountability is clear, and citizens know what role they play in that policy.

At the same time, these benefits can be transferred perfectly to a tourism context, where an SME will greatly profit from an open communication channel through which it could obtain information related to the city's transition and digital dimension, the agenda of activities (e.g., meetings, training sessions, workshops), performance indicators of the city such as its carbon footprint, and open data related to the company itself.

6.2.9 Citizen Participation Portal

The Participation Portal must promote collaboration between citizens, political groups, the business fabric, and the social ecosystem of cities.

This space is the place to listen to the opinions and contributions of citizens on the government's proposals, its regulatory projects, or its plans. A communication channel through its web spaces to disseminate its proposals and opinions to citizens.

It thus reinforces dialogue, transparency and closeness, as well as the democratic values of cities, promoting participation channels to make them more accessible and open. And at the same time, it promotes the use of face-to-face and digital media that increase participation and facilitate the maximum diversity of participants, adapting the channels of participation to the plurality and complexity of the people who share the cities.

Among the main characteristics of a participation portal are:

- Debates: Anyone can open discussion threads on any topic, creating independent spaces where people can discuss the proposed topic.
- Proposals: A space for anyone to create a citizen proposal and gather support. The proposals that reach enough support go to a vote to decide whether or not the issues that matter to us should be carried out.
- Participatory budgets: Allow citizens to propose directly and decide how to spend part of the budget, with rigorous monitoring and evaluation of the proposals by the institution – maximum effectiveness and control of resources with the greatest satisfaction for all.
- Voting: Secure voting systems for citizen proposals and for issues proposed by the institution. It allows citizens to decide easily, from their mobile, on the most important issues.

- Collaborative legislation: Any legislative text can be shared with the public to receive comments on any specific part of it. The comments are associated with the commented parts, using a colour code, which allows easy visualization of the parts that can be improved. It also enables the creation of spaces for prior debate associated with the text for better subsequent development.

In order to address said complexities, this dialogue space must keep certain topics such as tourism in the front line, since it is the only way of mitigating negative impacts over urban spaces and the daily life of citizens. Tools like this, which also allow the constant analysis of the tourism perception from locals, will certainly avoid critical situations where damage is irreversible.

6.3 Core IT components

Cities offer services to citizens that we can classify as the provision of public services of local competence (e.g., lighting, mobility, solid waste, public roads, territorial planning) and public administrative services (e.g., urban and activity licenses, education, services and social aid, education). These services use ICT as support for their provision, in many cases, they are information systems that aim to solve all the functional needs of the actors (e.g., citizens, workers, companies) involved in the complete management of the service.

The classification of administrative ICT information systems and ICT information systems for the provision of public services allows us to identify and classify 100 per cent of municipal applications. All of them must meet a series of characteristics from the design: security and interoperability.

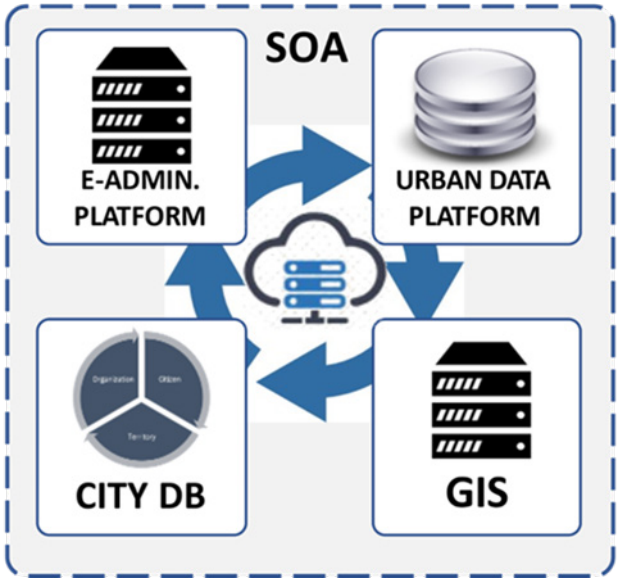
Security will be treated specifically in a latter section; in this case, it must be present in each of the layers in which the information and connectivity systems are built, and given that we must expect to be attacked through the weakest point, we must plan security well enough to ensure that that weak point does not act as a conduit to a generalized attack on all critical systems.

Computer applications must be built in a modular way to develop their specific functionalities and orchestrate services in a complex ecosystem, with perfectly defined communication mechanisms in reliable environments.

In this context, we can define a series of enabling, corporate or transversal elements for any local administration on these nuclear elements. The different municipal information systems will be able to develop and support the services to the citizenship and administration.

The following figure shows the nuclear systems of a city that must be built on a service-oriented architecture (SOA). This architecture is based on the construction of microservices or services with a specific and defined functionality on which more complex services can be orchestrated, with well-defined integration contracts that can be called by known systems through integration buses that offer security and confidence in the construction of electronic services.

Figure 28: Nuclear IT elements of a city



The main ICT core elements of a city are as follows:

- **Corporate databases**: They must contain the minimum information of those elements that are unique in any city: territory, organization and citizenship (also companies). In an SOA environment such as the one previously defined, it will allow the rest of the information systems to consult and update these unique elements.
- **Electronic Administration Platform**. The information systems of support to the administrative business have in common the management of the administrative file as elements of administrative action that contains documents, data and administrative actions. As will be seen *a posteriori*, the administrative processing requires as enabling elements of a comprehensive Electronic Administration: electronic records, electronic headquarters, a catalogue of administrative procedures, certified digitization applications, electronic identification systems, management of electronic documents, management of governing bodies, electronic signature holders, and electronic file. The different information systems should focus on their business needs, leaving the administrative processing to these transversal systems.
- **Geographic Information Management**. All cities have in common that they deploy their services within a territory. The location of all municipal assets in a geographic information system allows many municipal services to develop their management in a coordinated manner in a spatial reality. The integration of this spatial data offers excellent possibilities for open data, as well as analytical capabilities on spatial data.
- **Urban Data Platforms**. This constitutes the main data infrastructure of a city with integration capabilities of the Internet of Things and municipal information systems. This unique city repository (Big Data) allows analytical capabilities and services for citizens such as open data portal, city app, internal management and citizenship dashboards.

Concerning the ICT architecture, especially for these corporate databases, they must be created with a service-oriented architecture (SOA). A city must identify those services that must be transversal to the entire organization, which can provide microservices or services to the rest of the information systems: these will also be created in an SOA environment of service orchestration.

Cities must face complex challenges that affect many municipal areas, including the socio-economic environment. Additionally, the actions taken in a specific area of the city can affect the conquest of these challenges, which is why it is necessary to have a vision of the city as a system of systems that is also related to other cities whose relationship is also basic.

In this case, two key concepts appear in the management of a city. Firstly, the need for a corporate information system that encompasses the entire life cycle of the data and is constituted as the city's data infrastructure: this must provide the holistic vision necessary to face complex challenges. The second concept is that of interoperability, which must be thought about from the design stage. It has implications for the systems of a city and its relationship with other internal objects of the city and external objects.

This infrastructure must contain at least the following elements:

- Ability to ingest data from IoT devices and other information systems.
- Urban data platform with massive data capabilities, data analytics, context manager to relate different municipal areas in real-time information.
- Dashboards for citizens and for municipal services and politicians – the latter two to be able to monitor the challenges of the city, as well as facilitate strategic and operational decision-making.
- Open Data Portal, where those data sets of the city's data infrastructure may be useful for citizens and companies are published.

Interoperability, as we discussed earlier, is a radically important concept in creating robust, sustainable and scalable ICT architectures that support the new challenges of cities. The first decision on interoperability is to create or evolve towards a service-oriented architecture (SOA). The objective is the development of specific services that offer a concrete solution that any information system can use in the city, and even one in which different services can be orchestrated to build new aggregates.

ITU has already defined the concept of interoperability, and concepts such as minimum interoperability mechanisms (MIMs) also appear. The European Union has developed the European Framework and the Interoperability Reference Architecture as the main element for cities to exchange information.

The construction in cities of ICT architectures based on services having interoperability and security as default elements in the design of the solution is fully compatible with the strategy being followed in GovStack.

This architectural approach also makes it easily scalable, allowing it to meet another great challenge, for example, applying emerging technologies such as Artificial Intelligence, blockchain, Internet of Things, and digital twin.

6.3.1 Service-Oriented Architecture

On the path of the digital transformation of cities, a major critical element is the adoption of service-oriented application architecture (SOA).

The SOA architecture allows the creation of highly scalable information systems that reflect the business of the organization. In turn, it provides a well-defined form of exposure and invocation of services, which facilitates the interaction between different own or third-party systems.

Among these benefits, the following should be highlighted:

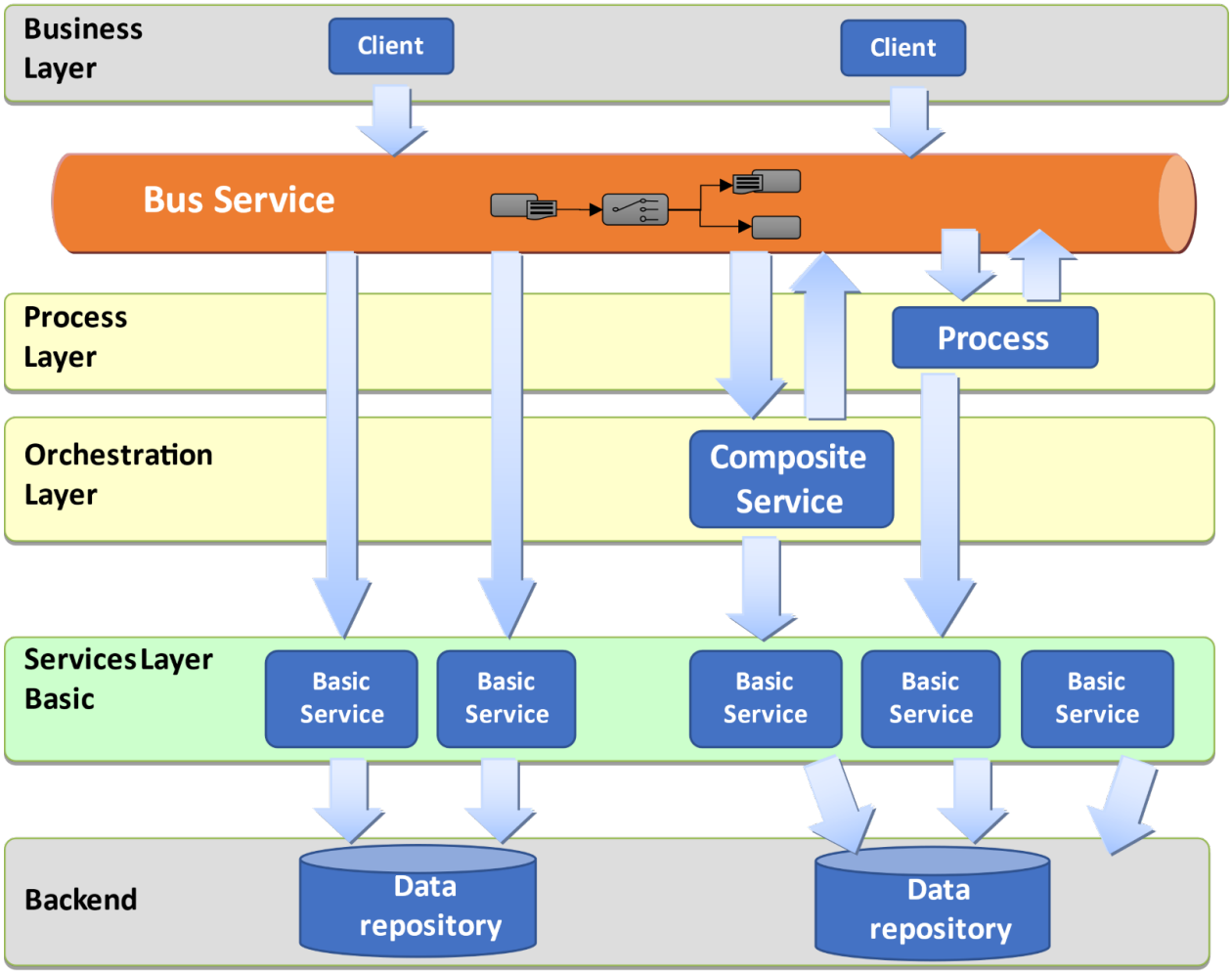
- Greater visibility of relevant information: Within the SOA architecture, specific components are included to define, generate and present, in real time, the selected relevant information.
- Greater flexibility, agility and scalability in IT systems to respond and adapt to changing requirements.
    - Process logic is not embedded in applications, which facilitates and simplifies its modification.
    - Highly re-usable technological services.
    - Significant reduction in the time needed to modify a service and/or implement a new one.
- Simpler and more rational technological infrastructure, with lower costs and simpler management.
    - New systems are integrated only once so that the integration costs are linear and not exponential.
    - Centralized systems management.
    - Central monitoring and control of the systems.

The SOA Architecture organizes technological resources as if they were services so that they can be disposed of without attending to their internal logic and facilitating their re-use. Its fundamental principles are as follows:

1. Clear separation between business logic and presentation logic.
2. Execution logic is divided into “services”, with clearly defined access and use procedures.
3. Any application or service, “duly qualified/identified”, may use another service in real time through the appropriate interface.

The basic outline of components of the SOA architecture is:

Figure 29: SOA architecture



For each of these layers, a city can adopt the following components:

- Basic services layer: Services that deal with accessing data based on open languages such as Java EE (CXF) with Contract-First methodology and made with the Eclipse IDE.
- Service bus: Point of mediation and communication between consumers of services and service providers. Some of the features of a service bus are:
  - Eliminates point-to-point connections.
  - High-performance lightweight intermediate.
  - Ensures compliance with security policies.
  - Centralized management unifies monitoring and follow-up.

- Ensures scalability and integration.

- Orchestration layer: Services that orchestrate several basic services that it invokes with calls through the service bus allows deploying SOA services.
- Business Process Layer: Services that implement business processes using composite or basic services that it invokes through the service bus.
- Business layer: Business applications (customers) that call the different services; basic, composite and business processes; through calls to the service bus.

6.3.2 City Database

We shall identify those ICT elements that are nuclear to any city and that must be faced with corporate will:

City Databases:

- Citizen database: The citizen is unique. A city should have a 360° view of all relationships that such a citizen has with the city. Offering personalized electronic services requires that any relationship of that citizen is inventoried and accessible by the same complying with all the requirements of security and privacy. Therefore, it seems appropriate that this corporate database contains basic information about the citizen such as first name and surname, address, language, identification number, and a list of information systems on which you can consult and initiate processes through the identification number.
- Territory Database: The administrative management of a city needs to be uniquely and unequivocally identified by any municipal information system. Thus, to refer to a building or a dwelling, an activity must be created and maintained by a unit with common criteria that ensure the unity of the urban configuration of the city.
- Organization Database: The administrative units of the city, its political and civil servants, and its workers must be managed centrally. And the administrative applications that require knowing the administrative organization must have the ability to ask about it.

6.3.3 Electronic Administration Platform

In many countries, legislation is being developed that protects the right of citizens to interact with the local administration by electronic means, with the ability to choose whether to relate in person or electronically at any time in the life cycle of the administrative activity in question.

This implies that each city must have an identified address on the Internet (electronic headquarters) where a citizen, using digital identification, can initiate any administrative procedure offered by that city, in addition to being able to be represented or represent another citizen and access their citizen folder where all the data, documents and status of all the electronic relations that said citizen has with his city must be shown.

Offering these electronic services to citizens requires a complete electronic administration platform, integrating business information systems to collect information and services. This integration should be done in such a way as to ensure privacy and security, which can be achieved with the citizen database and service-oriented architecture.

The following figure shows that administrative transformation requires addressing strategic, organizational, technological, interoperability-security and citizen services aspects, as well as specific indicators that allow the evolution of its achievement over the years to be verified.

Figure 30: Administrative transformation SSC

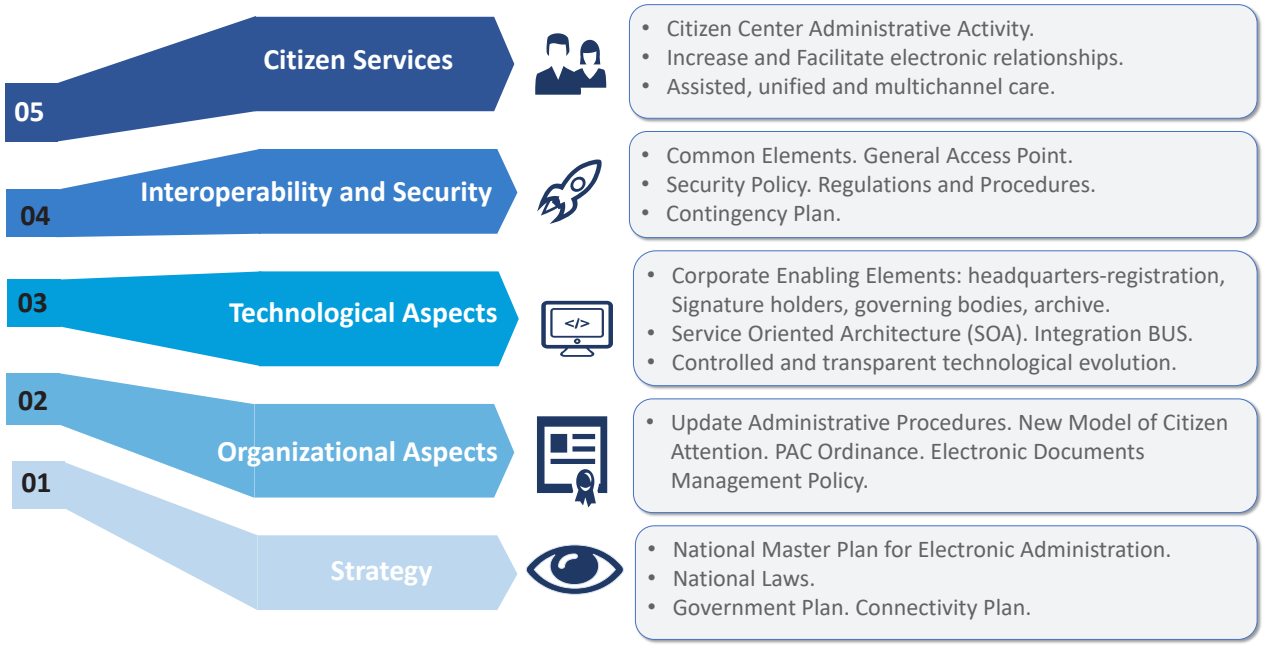
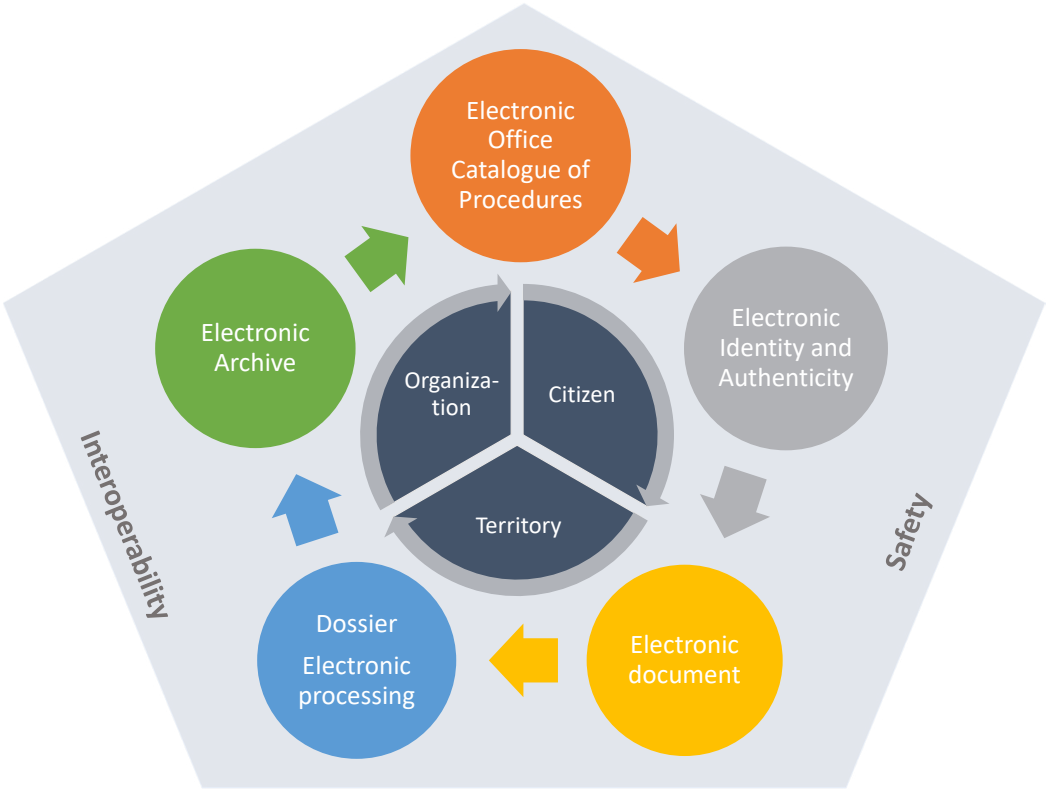


Table 2: KPI & achievement targets over time

Area	Indicators	Relevance	Achievement		
			Year X-1	Year X	Year X+1
Normative	Ordinance of electronic registration and Electronic Administration.				
	Total regulatory scope	30	50%	100%	100%
Organization	3..10 Creation of an e-Administration Commission; catalogue redefinition and revision of administrative procedures; communication plan; interoperability table.				
	Total organizational scope	120	20%	80%	100%
Documental	11..16 Classification, preservation, metadata and implementation in electronic documents table. Access policies.				
	Total documentary scope	120	5%	40%	100%
Technologic	17..26 Electronic Office; digital identity management; electronic signature; electronic registration, document management; digital archiving, document validation, notification, interoperability platforms.				
	Total technological scope	120	50%	80%	100%
Citizen Services	27..36. Comply with the electronic rights of citizens to interact with the Administration electronically.				
	Total scope citizen services	150	50%	75%	100%

The following figure shows the main enabling elements of Electronic Administration:

Figure 31: Main enabling elements of Electronic Administration



6.3.4 Catalogue of Procedures

The Catalogue of Procedures includes the list, and the associated information, of the procedures in which the administrative action of a city is specified.

The Catalogue has a double aspect:

- It is a tool for relations with citizens, by collecting all the information necessary for the relationship between it and the municipal administration (when, how and where to carry out management with the City Council).
- It is an internal management tool based on the management of electronic records of the city.

The Catalogue contains:

- Proceedings initiated at the request of a citizen, whose information can be consulted in the Electronic Office.
- Ex officio and internal management procedures.

It is the responsibility of the services of a city to keep public and internal information of these procedures fully updated.

Since the administrative concept of procedure can vary in different areas of the world, we should develop some basic definitions to understand the importance of developing a tool to manage the catalogue of procedures of a city and the importance of developing it before the electronic headquarters and the electronic management of city records.

Procedure: Specification of the administrative activity to manage the competencies that, according to the corresponding regulations, each administration has attributed.

- **Specific Procedures:** Procedures whose competence corresponds to a department. *Assumptions*: Granting of a tax benefit, a building licence, the authorization of a ford, etc.
- **Horizontal Procedures:** Procedures whose competence could correspond to all departments. *Assumptions*: Resources, subsidies, complaints, requests from other administrations, management of the expenditure budget, etc.

File: It is the concretion of a procedure before a real case. From the moment of its initiation, each file must necessarily be associated with a procedure of the Catalogue.

Procedures in the Electronic Office: In the Electronic Office will appear as "Procedures" those procedures that the citizen can initiate by submitting an application.

Electronic Registration: Registration of entry of the city where all the applications submitted through the Electronic Office are recorded. Citizens have the possibility of initiating a procedure via telematics from the procedure itself that is shown at the headquarters in the "*Procedures*" section.

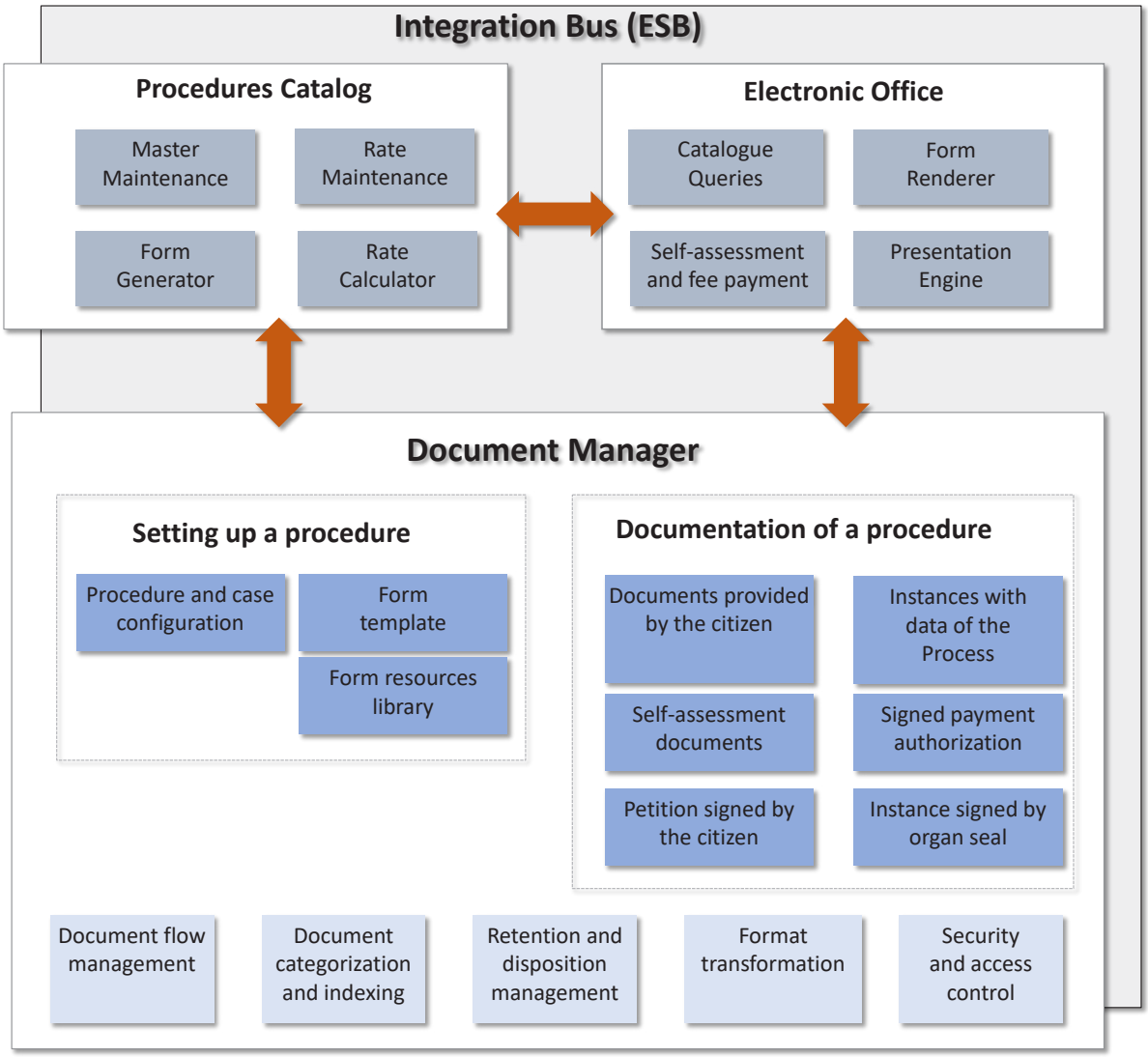
Form for the initiation of a Procedure: Form for the telematic request of a procedure from the Electronic Office. If the procedure can also be initiated in person, the accepted application form and the telematic *initiation form* must be consistent.

List of documents required for the initiation of a procedure: Structured list of the documents that will be required at the beginning of a procedure. This relationship will be the one that is automatically shown in the Electronic Office when the citizen is going to make a telematic request for a procedure. And it will also be the one that will be consulted by the check-in officials at the time when personalized attention is implemented.

Cases of a procedure: Different cases of the same procedure, which do not have the entity to be a different procedure, but which can determine differences in terms of the documentation to be presented or the initiation form.

We go on to describe the high-level components of a procedure catalogue solution, as well as the most representative communication interfaces, all from a functional point of view. Figure 32 illustrates the components of the architecture described in the following sections:

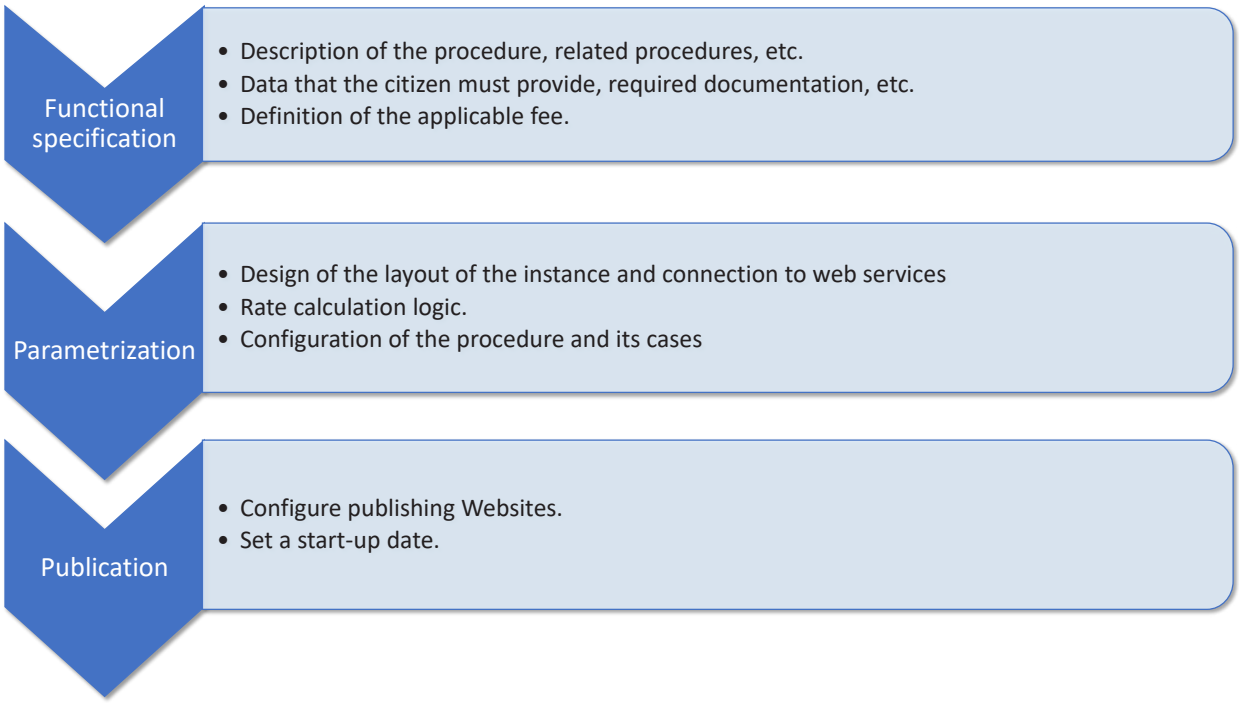
Figure 32: High-level components of a procedure catalogue solution



6.3.4.1 Catalogue of procedures component

The catalogue of procedures is a basic service of electronic administration that supports the municipal electronic headquarters and constitutes the source of information on the administrative procedures initiated at the request or ex officio for all the systems of a city. The most significant quality of this component is the possibility of completely carrying out the process from the definition to the implementation of a new procedure without the need to carry out evolutionary maintenance of the electronic headquarters.

Figure 33: Catalogue of procedures



The figure shows the process of starting up a new procedure in the electronic office, and, of course, the first step is to collect the functional information on the procedure to be modelled. Some of this information will be shown to the citizen in the form of descriptive literature, but another important part in addition to being shown to the citizen will be used by the presentation engine to self-configure and take the necessary actions.

The parameterization phase is the one that brings together the tasks of a more technical nature. However, most operations can be performed by functional users without technical knowledge. It must also be possible to calculate the fee if the procedure requires it, and it must be able to perform simple calculations, as well as those that require evaluating various fields of the instance form and carrying out checks by sections, dates or any other criterion.

The publication or execution of the procedure must be capable of being carried out immediately or deferred, indicating the date of its publication. The document manager will be in charge of releasing the publication of the procedure when the publication date is fulfilled. In the same way, it is possible to configure cases so that a procedure can automatically activate the operation of others. This functionality is especially useful in the event of a change in regulations that affects certain procedures, for example, a change in the requirements for a large family that requires new documentation.

Master Maintenance

In the catalogue master maintenance module, the taxonomies with which the procedures are categorized in the document manager are managed. This module must contain an engine for synchronizing taxonomies with other systems in the city so that the procedures are classified according to the relevant criteria for the areas or services involved in the processing.

Form Builder

This type of tool is required to design in a friendly way and with a high degree of flexibility in any form for the collection of citizen data. This tool should meet the following functionalities:

- Wide variety of basic user controls (labels, text boxes, folding lists, single (radial) or multiple (check) selection buttons, calendar, etc.
- Definition of blocks or sub-forms: possibility to define re-usable blocks facilitating the construction and maintenance of the forms (for example, data of the interested party, vehicle data)
- Multilanguage: Possibility to add multiple languages for a form.
- Rendering in edit or read-only mode.
- Assisted integration with data sources in web services or database.
- Compliance with W3C XForms standards.

Maintenance and fee calculator

The fee maintenance module is where the logic for calculating the fee for each procedure case is defined. The user accesses the definition of each fee in a simple way from the name of the procedure and case. It has an integrated environment for editing and testing the logic of fees.

The fee calculator is a particularly significant integration service (web service) that receives as a parameter from the external system (the electronic office) the procedure and case code, as well as the instance form with the data provided by the citizen and that will be used to calculate the rate. The service checks that the procedure and case pair have a rate, and then extracts the data and evaluates the calculation function by returning a numerical value to the external system.

Integration Services

The catalogue of procedures must offer the data to the rest of the systems through web services. There is a wide catalogue of services to obtain the list of procedures, details of a procedure, list of cases of a procedure, list of values of classification taxonomies, a calculation of the rate, and so on.

6.3.4.2 Components in the citizen portal (electronic office)

Up to this point, the components and services that allow defining the administrative procedures within the catalogue of procedures and sharing the information with the rest of the systems have been described. This point describes the components that are integrated on the side of the client system (portal or electronic headquarters) and that consume the services of the catalogue.

Catalogue queries

The client application consumes the data information services of the procedure and cases offered by the catalogue. The information consumed can be descriptive for information of the interested party (citizen, manager or public employee) or of an operational type, serving as input data for the presentation engine.

Self-assessment and payment of fees

An essential component to allow the completion of any type of procedure is the module for obtaining self-assessment and payment manager. The module executes a micro-tramitation flow that involves obtaining a self-assessment reference and a printable document in case the payment is to be made manually. Subsequently, the payment process is configured with the data entered by the citizen in the case of telematic payment, the payment authorization document is signed by means of a digital certificate and a document of justification of the payment is delivered where the NRC of the transaction appears.

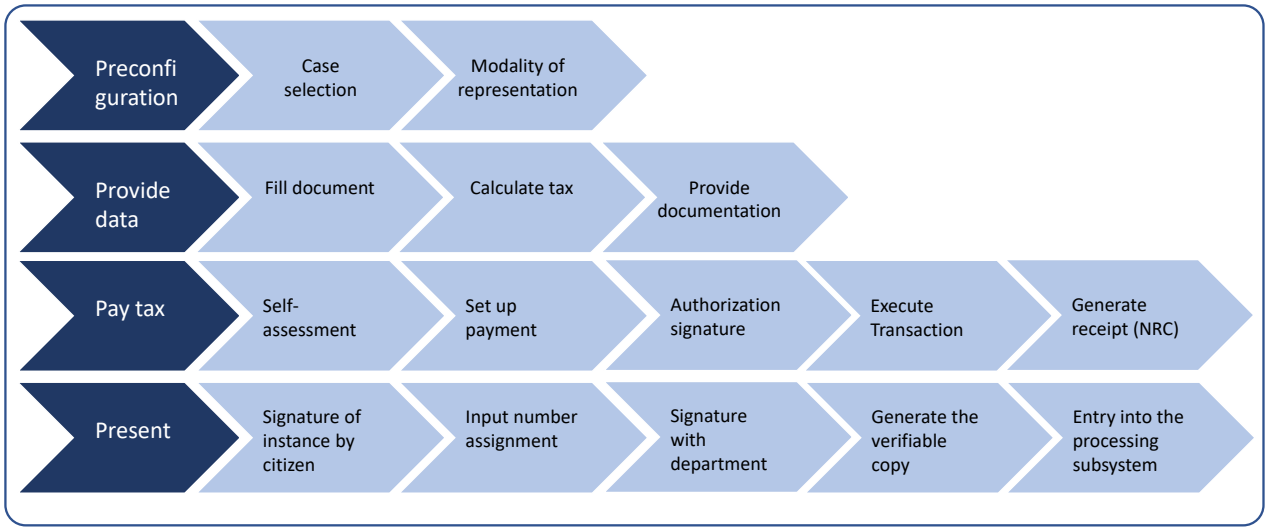
This module reports the result of the transaction to the presentation module and delivers the documentation to be stored in the document manager.

Presentation Engine

This component constitutes the heart of the operation of the electronic headquarters of a city. It must be responsible for orchestrating and managing the process of presentation of a procedure by a citizen until the moment of delivery of the procedure is fully completed and signed by both parties to the processing subsystem.

The following figure illustrates the statuses managed by the paperwork filing engine:

Figure 34: Presentation Engine



The presentation engine allows keeping as a draft a procedure initiated, thus facilitating the citizens to complete the required information as they have it, or simply park the presentation of the procedure at his convenience or comfort.

6.3.4.3 Document Manager

The third functional block required in the solution is the document management infrastructure, common to the catalogue of procedures and consumer application of the catalogue services (headquarters or other systems). The integration of a document manager as a base component of the solution is decided on the basis that a large part of the services constitute a *de facto* standard of the software industry, analogous to the services of a database management system.

The document management block is abstracted into two components that symbolize firstly the functionality offered by the system, and that is not developed ad hoc for it; and secondly the information that is managed by the system.

Documentary model

An aspect of the solution that must be taken into account is the functional definition of the contents (documents, multimedia objects such as images and video, plus their metadata) that are stored in the document manager. This definition constitutes the documentary model or metamodel that governs the behaviour of the document management system. However, as this model can be much more extensive (for example, news, edicts, web content of the headquarters), we will stick to highlighting the definition part that applies to the catalogue of procedures and engine of

presentation of procedures. Thus, two high-level categories are differentiated in the documentary taxonomy:

A) **Contents or configuration elements of the system**: These are the ones that are introduced from the catalogue of procedures and serve to store the functional definition of the procedure. This includes the definition (descriptive and operational) of the procedure and its related cases, the forms definition of the instance form, as well as the procedure manual, flowcharts and other documentation related to the administrative procedure.

B) **Contents or documents of the procedure**: These are the documents generated by the system or provided by the citizen during the completion of the procedure. These documents begin by being categorized as drafts or parts of a "pending procedure" to end up being consolidated during the submission process and transferred to the processing subsystem. The functional capabilities of the document manager (e.g., retention and disposition management, categorization for historical archive, document flows) are mainly applied to this type of document. Although the documentation of the procedure is presented from the headquarters and with the entry into the processing subsystem, the life cycle of these documents will continue with the processing, and some of them will continue to be managed for life in the electronic document archiving system.

6.3.5 Records management

The administrative management of a local administration is substantiated through instances and files. These items of administrative management can contain, for example, documents, proceedings and resolutions on which actions are developed that have been modelled over time by legal and functional aspects very marked by the support, in most cases the paper.

Let us start by trying to identify the complexity of the integral management of the files. A file is made up of a set of documents: consequently, we must first solve the problems associated with them, namely that in some cases they are provided by the citizen; whereas in many cases we require proof of the identity of the signatory and the time of signature – which, in some cases, we must exchange with other administrations.

It is necessary to consider the complexity of electronic management and preserve the citizen's right to act at any time by physical means (documentation and paper instances), and solve the problems associated: face-to-face or with traditional and analogue channels allowing the initiation of files through electronic headquarters; verifying the electronic identity of the author or signatory of the documents; digitizing certified documents of paper origin; preserving and retrieving electronic documents, copies and conversions of electronic documents; and authenticating paper copies of electronic documents.

It is also necessary to study the procedural complexity of the administrative and political management associated with the life cycle of a file, resolving aspects such as resolutions, informative

commissions, municipal plenary sessions, making files available, and administrative documents as well as economic reports associated with files.

In the implementation of electronic file management, two main strategies appear. The first is to use vertical file management applications that have a more mature resolution of the documentary, electronic and procedural problems. However, this requires a, not always achievable, effort to offer homogeneous services of initiation, access, authentication, and archiving of the files. The second is to develop basic corporate enabling elements in the management of files: electronic site, digitization, signature, archiving, conversion on a generic implementation of the actions in the files, and a very integrable implementation with specific management applications or file management, with very specific requirements such as the tax area or contracting.

The second strategy is the only one that we believe can be successful in the long term in the comprehensive electronic management of files for a medium or large local administration. For small local administrations, they should demand a solution based on the second strategy from supra municipal entities because of the lack of resources to address integral solutions.

We call "*the file*" the ordered set of documents and actions that serve as background and basis for the administrative resolution, as well as the proceedings aimed at executing it.

A file can be described as the list or lists of documents that make it up, along with the documents themselves. If this relationship or list is electronic, we can say that we have the electronic file, regardless of whether the documents that make it up are in electronic format or in the paper support.

The electronic file, which has to be unique, must maintain its documentary and processing integrity; moreover, the documents of an electronic file must not be deleted and entered at the will of the user (as if it were a folder with files from Windows Explorer) because in this way, the integrity of the file could not be controlled and would not be reliable.

The processing will have to be electronic through a computer application (let us call it the processor or file manager). The processing of the files must be broken down into a series of tasks, phases or steps through which the processing of this can be completed.

These tasks may be sequential or parallel depending on the time of the processing in question. For example, the request for reports may be made in parallel in most cases, but the resolution of the file must be carried out sequentially.

The documents of an electronic file are born from the processing of the same, and what is processed in it is justified by the documents that accredit it.

In relation to the electronic management of records of a city, we define the business services and information services that might be necessary for any city.

6.3.5.1 Business Services:

- **General Entry Register:** Registration in the system of the instances presented by citizens.
  - *Bulk Registration and Maintenance of Instances*
  - *Automatic registration, maintenance, automatic distribution, sending and receiving Shipping Relationships*
- ***Document Processing**: Creation and* management *of files from the instances.*
  - *Document analysis*
  - *Movements between units*
  - *Record of actions*
  - *Annotations*
  - *Notifications / Mail*
  - *Completion of files*
  - *Register of Proposals*
  - *Statistics of Administrative Management*
- **General Departure Register**: Centralization *of shipments to citizens.*
  - *Reception, automatic numbering, manual numbering, return and consultation of Exit Relations*
  - *Consultation and Maintenance of Notifications without File*
- **Post office**: *Shipments to third parties by* mail.
  - *Reception, maintenance and summaries of post office relationships*
  - *Sending to the post office*
  - *Consultation of postal items*
- **Queries**: *Consultation of any data of Instances or Files.*
  - *Instances*
  - *Instance movements*
  - *Consultation of files*
- **Books and Reports**: *Information predetermined and prepared* for *printing.*
  - *Necessary by legal requirements in the Public Administrations.*

- **Statistics**: *Statistics that provide information on the procedures carried* out.
  - *Instances received by registry.*
  - *Types of files initiated.*
  - *Procedures by type of file.*
  - *Generating units by the type of dossier.*
  - *Files generated per unit.*
  - *Records reported by unit.*
- **General Operations (Table Maintenance)**:
  - *Maintenance of the tables (CRUD) of the system that are maintained by the users.*
- **Management by Administrative Unit**: Specific operations of a unit.
  - *Purchasing Board*
  - *Certificates of occupancy*

6.3.5.2 Information Services

- Actions on files: Tasks carried out that are associated with a specific file.
- Grouping (of files): Grouping of files so that their treatment will be simultaneous.
- Annotations: Observation or comment on a file.
- Contributions: Document attached to a file; may be additional instances or other documents.
- File: Basic document on which the procedures are centralized. They originate from an instance or directly by the city council (ex officio).
- Instance: Document that includes the requirements of a service made by a citizen to the city council of Valencia.
- Interested party: Natural or legal person who has initiated an instance.
- Notifications: Communications from the city council to those interested in a file.
- Check-in: Administrative unit specialized in the reception of citizens' instances or files redirected from one administrative unit to another.
- Check-out: Administrative unit specialized in the collection and control of notifications.
- Sending Relationship: Grouping of documents sent from one administrative unit to another.
- Post office Relationship: Grouping of documents to be sent from an administrative unit to a post office.

- Exit Relationship: Grouping of documents to be sent from an administrative unit to citizens.
- Representative: A natural person acting as a representative of a legal person.
- Administrative unit: Organizational unit that offers a set of related services, performing a defined set of actions.

6.3.5.3 Modelling of procedures

Studying the models of processors that exist in the market, we could classify them into two types: those that guide the processing of a file from beginning to end; and those that guide in phases or procedures.

Those that guide from start to finish have the drawback that they do not treat exceptions very well. And those that guide in phases or procedures have the disadvantage that the processing user must know what to do at each moment of the processing.

In both cases, the question that arises is whether all the existing administrative procedures in the organization must be modelled to implement the electronic file.

We can ask this question from another angle: should the electronic file be implemented in all procedures or only in part?

This is perhaps one of the most important decisions of the organization in the process of implementing the electronic file.

There are two answers according to the point of view of each one: there are those who think that the implementation of electronic administration in the processing of files should be done step by step; and there are those who think that the change must be total, i.e., that it must be implemented at once.

Each of the two options has its risks.

- The first option, partial implementation, has the risk of distrust with the electronic file because it is living with the paper file, which means two different ways of working for some users of the organization. In addition, some legal aspects of the processing of files are complicated such as the treatment that must be given to the Book of Resolutions when some are made on paper (paper files) and others in electronic format (electronic files). Or, for example, the functioning of collegiate bodies.
- The second option, full implementation, has the risk that the magnitude and cost of the project will increase in proportion to the size of the organization. In both cases, there is a way to implement the electronic file without having modelled all the administrative procedures of the organization: model subprocesses common to any administrative procedure.

If the common administrative procedure is studied thoroughly and broken down into parts used in the processing of any file, common subprocesses are obtained such as requesting a report, making a request, providing documents, resolving a file, or finalizing a file.

Each of these subprocesses will provide or generate a series of documents that will be associated with them automatically and included in the file (documentary and processing integrity).

Having these modelled subprocesses, we can use them to process any type of file, whatever the procedure.

If the procedures are modelled by chaining threads from start to finish, we will have a processor that will guide the user from start to finish.

On the other hand, if the threads are modelled but it is left to the user to decide which one to execute at all times, we will be talking about a processor that guides in phases or procedures.

In this way, we can manage electronic files of any city **on these basic elements for electronic files management.**

- Task: Atomic action that a user of the application (for a specific working group of an administrative unit) can perform on a specific instance and/or file.
- Procedure: Grouping of tasks that pursue a specific purpose within the processing of files. Example: The procedure "Pass to Manager Service" will group the tasks of entering in a shipping relationship, sending said relationship and receiving it at the destination.
- Action: Grouping of procedures to cover a complete functionality within the processing of files. Example: The action "Requirement" will group the management and notification procedures.

6.3.5.4 Documents that form the electronic file

Analysing samples of files from a city, we can find documents of different origins and typologies:

- Documents provided by the citizen, on paper or in electronic format, for example, an instance with its attached documentation.
- Documents prepared by the organization itself, for example, a report or a resolution.
- Documents prepared or completed by external bodies or other administrations; for example, acknowledgements of receipt from mail, certificates from the tax agency.
- Photocopies of official gazettes or press.
- Documents from other computer systems of the organization or computer systems of other Administrations, for example, a list of the economic application of the organization, screenshots of the Cadastre system or the General Directorate of Traffic, telematic queries made to external computer systems (e.g., tax agencies, social security, employment).

- External or internal data transferred to a document, with or without signature such as notes of communications with the interested party of a file, explanation of the process of calculation of some sanction, or observations.

The electronic file must be prepared to contain any document of the statements.

Certified scanning

In the vast majority of cases, the document will arrive on paper, either through the face-to-face entry records or by the appearance of the interested party. Cities must convert these paper documents provided by citizens into electronic administrative documents with full legal validity.

This process is called certified document digitization and is usually accompanied by hardware and software that must meet a series of technical requirements for the process to be homologable and legally correct:

- The whole conversion process must be done from beginning to end automatically and without human intervention.
- The electronic document obtained must contain the electronic signature of a seal of the body that holds the competencies to make this certification.
- Approved hardware and software should be available. The tax agency has a software approval procedure for the digitization of invoices.

Electronic signature in documents of own elaboration

In this case, we can find two types of documents: those that we can write using a word processor of any office application (e.g., Microsoft Word) or text editors included in web forms that will directly generate (normally) documents in PDF format.

In either case, it is advisable to convert all the documents generated in the organization itself to a common format before being signed, either PDF or PDF/A.

The next thing will be to determine the signature format and the computer tool or application to perform it.

As for the format, it is very important to get the decision right since the cost of a subsequent change can make it unapproachable.

There are several signature formats recognized and used in the administration, but it is essential to take into account security and interoperability to guarantee the exchange of documents between administrations.

Data exchange with other computer systems

Nowadays, the number of web services that the different administrations are offering to the rest through the different interoperability platforms is growing: @firma, enabled electronic address, various records, SVDI, SVDR, information from the Tax Agency, information from the TGSS, among others. The information obtained through these means must be reflected in a document before it is incorporated into the corresponding file. In this process, we can apply an electronic signature or not apply it (it is convenient to apply it).

Other documents or data provided to the file.

As mentioned above, many files provide photocopies, documents or data contained in documents to complete the administrative files. For example, photocopies of official or press bulletins are provided to accredited publications.

Normally these documents do not carry signatures, so their incorporation into the electronic file can be done in two ways:

- If the original source is accessible via the Internet, it will be enough to print the required pages in PDF format using any virtual printer we can find today (e.g., PDFCreator).
- If the original source is on paper, we must use the Certified Digitization process to convert the papers into authentic electronic copies.

6.3.5.5 Electronic file and governing bodies

A fundamental part of the processing of the files is their resolution or approval by the governing bodies. Therefore, we will not be able to implement the electronic file fully if the passage of the same through the governing bodies, whether single-person or collegiate, is not taken into account or properly designed.

The most complex part will be the passing of the files through a collegiate body. It will be necessary to contemplate all the documentation that is prepared in a session of the collegiate body and what part of it must appear in the file, thus justifying its passage through the body.

6.3.6 Other required components

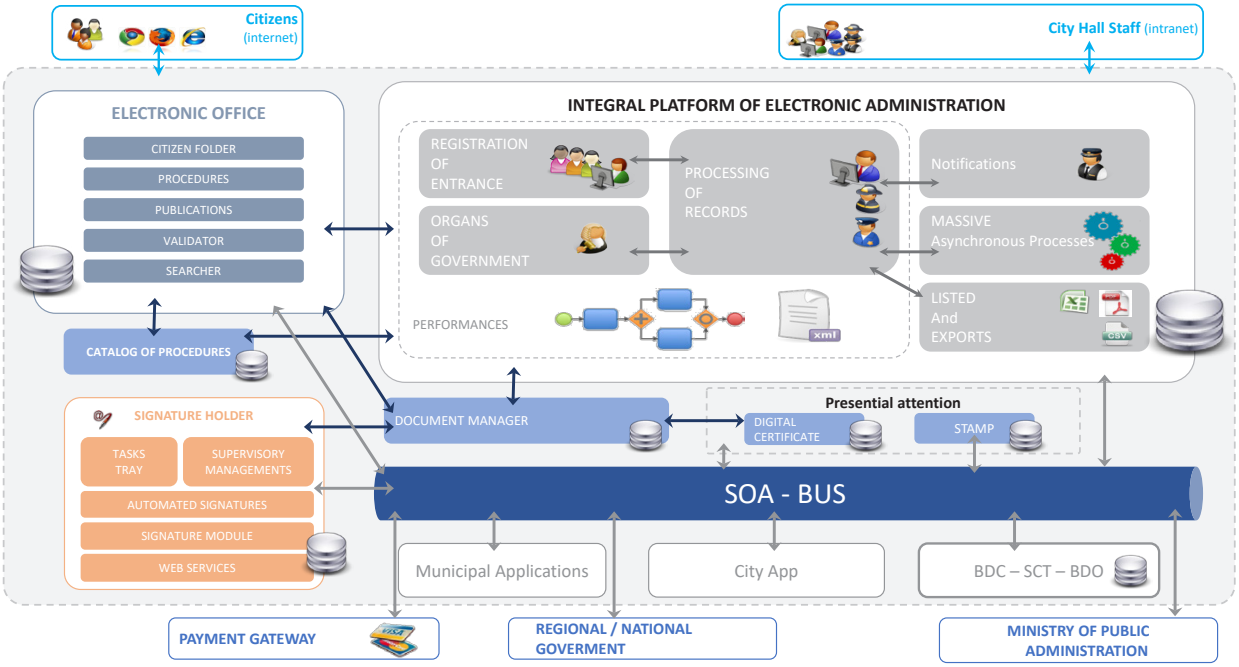
In the implementation of the electronic file, in addition to the file processor and the application of Certified Digitization, it will be necessary to have other components without which we will not be able to talk about a complete electronic administration.

As a summary, the essential components are presented with a small description of why they need:

- Electronic Signature. It is advisable that electronic signatures are made in an application independent of the processor, where not only documents of files are signed but also any type of document. In this way, the implementation of electronic culture in the organization's staff can be streamlined.
- Electronic Edict Board. It will be necessary to accredit the publication of advertisements or electronic edicts.
- Electronic Notifications. For when the citizen requests to be notified by electronic means.
- Electronic Archive. It is the destination of the finalized electronic files.
- Databases of Citizens, Territory and the organization. They will be necessary to be able to uniquely identify a citizen in the electronic world, as well as any division or direction of the territory or any employee of the organization.

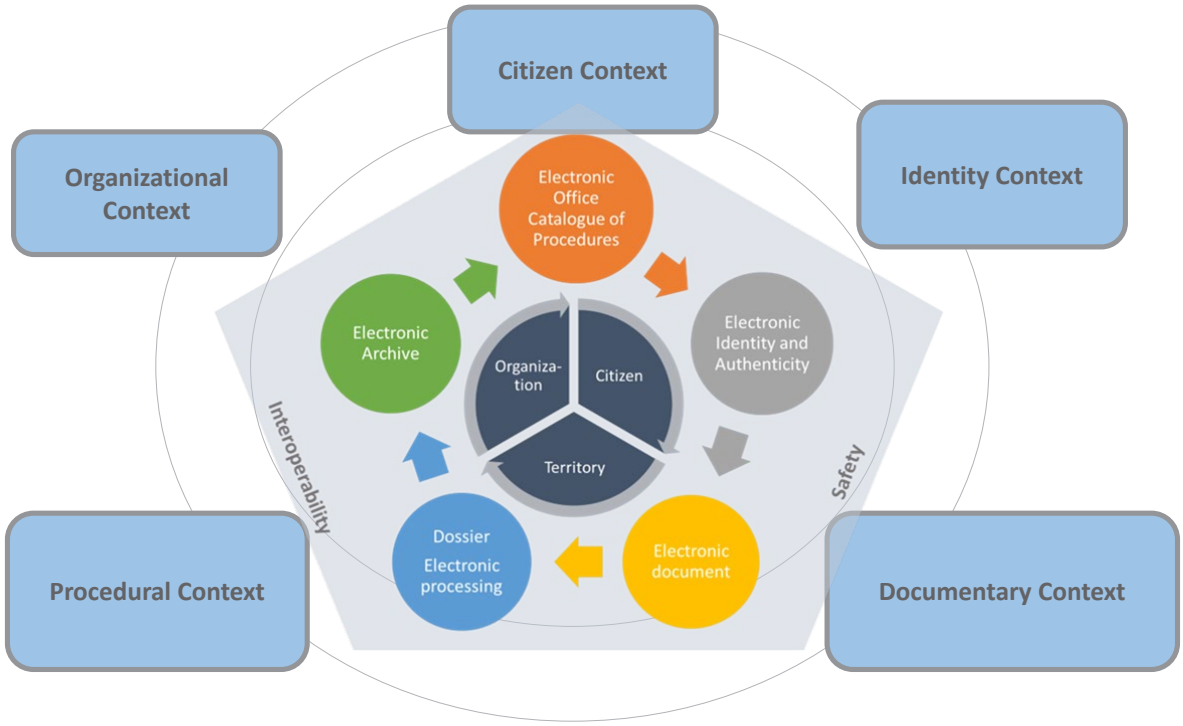
The following figure shows a holistic view of the administrative procedure architecture with the main components described previously:

Figure 35: Integral Platform of Electronic Administration



In short, a complete eGovernment solution must resolve the following contexts.

Figure 36: Context for a generic eGovernment Solution



- **Citizen context**: The electronic site of the city should provide a complete administrative procedure catalogue allowing citizens to initiate any of them. At the same time, it must contain a citizen folder where it can obtain any personal information, data and documents the city has from the citizen. At the same time, the citizen context should permit to receive any electronic notification of the city. The citizen folder and the notification functionality should be completely integrated to be federated with a point of general access at the regional or national level. Citizen context requires a citizen database to integrate the information related to all the relationships of the citizen with the city.
- **Identity Context**: User-centred electronic administration requires putting the citizen at the centre; in the electronic sphere, it implies managing a secure electronic identity to identify electronically the greatest number of citizens regardless of their origin. In this context, the functionalities of empowerment, representation by a natural or legal person and electronic authorization by an official must be resolved.
- **Documental Context**: Cities must define their electronic documents complying with all security and interoperability mechanisms. To do this, it will also define the certified digitization process to transfer paper documents to electronic ones with all the legal guarantees. To do this, they must define the set of metadata for each type of electronic document that allows the complete management of the life cycle of the electronic document, as well as its archiving.
- **Procedural context**: The city must enable an electronic file management application for the complete cycle of the same, from its initiation in the electronic headquarters or service office

to the resolution of the same by a government body. It is very important that this electronic file management be able to manage all the city's files. Therefore, we recommend that you develop an application driven by administrative actions of the administrative service instead of trying to completely automate the procedural flow due to the enormous disparity of files and the enormous number of cases that can arise in it.

- **Organizational context**: The city must create a single organizational database to manage the people in the organization and the organizational units centrally. Given that the administrations can work together, it is important that the coding of organizational units is known by external public administrations, if possible, with a single directory (DIR3). In this way, for there to be true administrative interoperability in a country, the catalogue of electronic procedures also needs to be uniquely identifiable (SIA).

6.3.7 Geographic Information Systems

The system must include an extensive database of geospatial content that currently exists, from official and reliable sources, in the form of layers, maps and applications.

Currently, there are thousands of public and private organizations that publish and share their data on different online platforms. These data include information such as roads, real-time traffic status, weather data, elevation profiles, updated satellite imagery and administrative boundaries.

Thanks to these contents, you can access a series of updated base maps, vector and raster, ranging from topographic maps and satellite images, to OpenStreetMap, among others.

The GIS system has to be highly interoperable at different levels, for the large type of data and services whose integration it allows, as well as for the types of data and output services that are *de facto* market and OGC standards.

It has to be characterized by being a platform open to developers, with different APIS to be able to extend specific functionalities, automate tasks and integrate with other municipal systems. To do this, it has a REST API from which you can integrate the published geospatial services with other applications.

You must include an API so that you can automate management tasks and perform spatial analysis in combination with other data science libraries.

Should you need to expand or make new developments, you must have the APIs and SDKs on different programming languages to be able to deploy native applications on multiple platforms.

Advantages and key points

Listed below are some of the advantages and key points of a robust GIS solution:

1. Data management and service publishing in a way connected to the corporate database.
2. Portal of administration of data services, maps and applications, manager to define users, roles and levels of access to these services. Possibility of joining the Corporate Active Directory.
3. Ability to share layers, maps, and application services at different levels: private, to one or more groups of people, to the entire organization, and open to citizens.
4. Powerful web map builder (Web Maps), with different capabilities such as advanced configuration of styles and symbolization, configuration of pop-up windows or attribute tabs, filters and visualization by stairs, among others.
5. Content included in the GIS platform, from various basemaps, street locators and coordinates, sociodemographic variables, transport networks, etc.
6. Availability of several templates and application builder, including the ability to create them without the need to develop, simply through configuration.
7. Visual and simple environment for the construction of viewers and applications; with the possibility of configuring different widgets of functionalities, texts and layout on the screen, and the appearance of the viewer.
8. Possibility of re-using the created applications. In this way, you can create new web applications in a short time and adapt them to the specific needs of different users.
9. It does not require external development, thus facilitating the maintenance of the applications deployed by the internal GIS team.
10. With the GIS platform, internal and external interoperability must be improved since it allows for the easy sharing of the web services of maps and features by REST and/or OGC protocols.
11. Integrable to other corporate systems through available APIs.
12. Rapid deployment of solutions for projects thanks to the capabilities of the GIS platform.
13. Product support for the strict quality controls in its development, and for the local technical support services for any question.
14. Availability of careful documentation of all GIS products and a large number of training materials, many free, which allow to considerably flatten the learning curve.
15. Wide geospatial community of users that allows the generation of important synergies between users and the technology itself, improving the products to adapt to the specific needs.

6.3.8 City Platforms

Therefore, from the city's perspective, a Smart City platform that allows the control of multiple applications will facilitate a more efficient and effective control of infrastructure and public services. It will also allow economic efficiencies and play a fundamental role in achieving environmental and social objectives such as reducing crime and improving mobility. In addition, the deployment of other applications can be speeded up and simplified.

The SSC Platform has capabilities for accessing different sources of information, sharing resources, analysis capacity, and coordination of services (orchestration) based on predictive analysis. The concept of horizontality provided by this platform, in which information from all sources can be used arbitrarily, is key in the Smart City concept.

Defining a standardized architecture of Smart City management, which is a platform or city operating system, is the object of increasing attention, especially in aspects such as interoperability between SSC Platforms, between these and legacy applications, proprietary information systems, and with MTC devices and IoT.

There are different solutions on the market that try to cover this objective, are modular and pay special attention to the integration of IoT devices, interoperability with legacy systems and the incorporation of specific functional blocks such as Big Data or Artificial Intelligence. In this sense, a significant standardization effort has been made to ensure that the architecture model can be compatible with the different implementations of the market and guarantee interoperability.[48]

As an example, Recommendation PNE UNE Standard 178104:2017 "*Comprehensive systems for a smart city management. Requirements of interoperability for a Smart City Platform*" defines the concept of interoperability based in a layered structure model that enables the integration of different systems through an open and, if possible, standardized exchange mechanism. The standard also presents the definition, requirements, and interfaces between the layers of the SSC Platform, which powers and facilitates the deployment of SSC services and the re-use of existing applications.

In the UNE Standard 178104, the basic elements of each layer have also been defined to ensure that the SSC Platform provides the essential services required by the city and, at the same time, enables the generation of new services and applications that improve the quality of life of citizens. The model has been developed to ensure maximum efficiency, scalability and integration, and promote local and social-economic development through competitiveness and innovation.

The second edition of this UNE Standard 178104 (2017) takes into account the work promoted by Spain in Study Group 20 on IoT and Smart Cities of ITU-T. This architecture is compliant with the one described in ITU-T Y.4201.

In summary, a Smart City Platform allows:

- Real-time knowledge of the city's state by collecting information from the city, citizens and businesses, whilst meeting the pertinent privacy requirements.
- The coordination and provision of available information by the city's maintenance services managers.
- The dynamic management of activities according to current data, available resources, and objective quality of services.
- Decision-making by returning the refined information to the systems in charge of executing the different actions.
- The establishment of channels of interaction with the city government and citizens through specific subsystems that establish bidirectional flows of information.
- The offer of open data and capabilities to developers to facilitate the creation of an ecosystem of applications on the Platform creates additional value for the citizen.

6.3.8.1 Functional requirements of a Smart City Platform

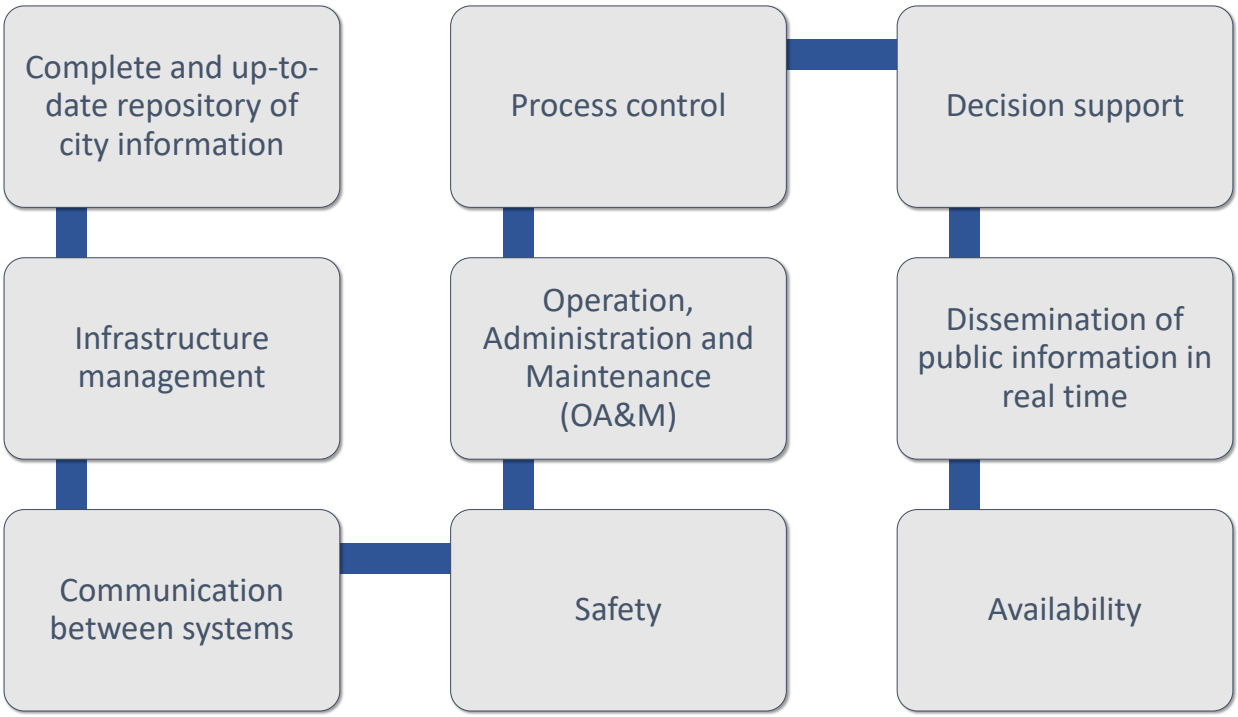
In summary, a Smart City Platform allows:

- Real-time knowledge of the city's state by collecting information from the city, citizens and businesses, whilst meeting the pertinent privacy requirements.
- The coordination and provision of available information by the city's maintenance services managers.
- The dynamic management of activities according to current data, available resources, and objective quality of services.
- Decision-making by returning the refined information to the systems in charge of executing the different actions.
- The establishment of channels of interaction with the city government and citizens through specific subsystems that establish bidirectional flows of information.
- The offer of open data and capabilities to developers to facilitate the creation of an ecosystem of applications on the Platform creates additional value for the citizen.

6.3.8.2 Functional requirements of a Smart City Platform

In a very summarized form, the minimum functionalities that a Smart City Platform must have, are detailed in *Figure 37*.

Figure 37: Functional requirements of a Smart City Platform



6.3.8.2.1 Complete and up-to-date repository of city information

- Host a common, universal, maintained, accessible and classified catalogue of unique and standardized data of the city, including its assets (the maintenance of the same will remain the responsibility of the management systems that generate them).
- Allow transversal analytical visions of the city based on these data.
- Facilitate and universalize the integration of data and legacy of existing solutions in the city.
- Provide open interfaces for the development of intelligent applications based on city data.
- Ensure the security and integrity of data, as well as user information.

6.3.8.2.2 Infrastructure management

The Platform will support centralized, secure, and multiuser monitoring and operation on the different resources, elements, or systems of a city:

- Access to data from sensor platforms, databases, and information from other applications.
- Actions on actuators (sensors) through standardized solutions.
- Record of the different activities that take place in the system.
- Management of the maintenance of equipment and infrastructures.
- Support standard monitoring protocols such as SNMP or JMX.

- Integration with other systems and applications such as systems for energy management and equipment operation (e.g., sources, lighting, building management); traffic light control; public transport; environmental stations; water management (irrigation, sewerage); garbage collection; video surveillance; public and regulated parking; electric vehicle charging points; citizen information systems (complaint systems, notification of incidents on public roads, urban emergencies, social networks, and tourism); social networks; corporate ERP; municipal GIS; and sensorization systems.

6.3.8.2.3 Communication between systems

The platform must allow communication with the different systems integrated into the city.

- Provide the necessary interfaces so that events from one system can trigger actions in other systems.
- Use APIS and standardized protocols for communication between applications and other platforms or management systems.
- Have the capacity to be extended to support other communication protocols like communications between systems that allow the execution of complex functions such as traffic light regulation to favour access to emergency services in the event of an accident, together with the notification to organisms involved.

6.3.8.2.4 Safety

Safety is a basic element of the system since the Platform will store critical information for the functioning of the city and the data of citizens protected by law.

The SSC Platform should implement tools or systems that allow the following tasks:

- Back up critical information.
- Guarantee non-repudiation in the safety net.
- Support data anonymization.
- Ensure data security and integrity.
- Support authentication and authorization.
- Control access to the Platform and all the elements that are accessed through it: sensors, Scadas, control centres, databases and other applications that are accessed through it.
- Ensure confidentiality in communications with the Platform.
- Ensure confidentiality of data access so that each role can see only the data to which it has access.
- Define and manage security policies.

- Provide a central and easily accessible module (via web) for the Administration of users, roles and permissions.
- Integrate existing user repositories as user records from local authorities or other user databases.
- Have the capacity to extend to adapt security mechanisms to the needs of each city.

The Platform must ensure the privacy and security of the data stored or managed by the solution, especially in a shared resource environment (PaaS: Platform as a Service). Likewise, it must be possible to define different access profiles to the different types/groups of data, so avoiding their inappropriate use.

The Platform must guarantee the secure sending of data to and receiving data from the devices connected to it, and its secure distribution to the applications that require it. At a minimum, authentication of the elements that originate the data and applications that require access to those data must be implemented.

The Platform must allow the definition of different roles and levels of access on the data, functionalities, and services of the Platform, authorize or deny access to the different applications and define the privileges required to act on a certain set of data.

Users of the SSC Platform may be individuals or applications that consume services or information. Different types of access for users should be considered based on different roles such as:

- System administrator
- Operator
- Managers
- SW clients of other applications

Role/permission management should be set for at least three levels of security:

- **Access to data**: Limit the information that each user can view. For example, a user of a certain service will have access only to the information corresponding to the data of its service, and to global data like General data such as global averages, deviations, or others obtained from the joint processing of the data corresponding to all the services.
- **Access to SSC Platform elements**: Limit access to reports and dashboards configured on the Platform. For example, a service user will only be able to access the reports defined with the data corresponding to their scope.
- **Functionality**: Delimit the actions that certain users can perform based on their profile. For example, a report user will be able to determine which reports and objects a consumer user has access to. Another example would be that consumer users would only query reports that they have permission to access.

6.3.8.2.5 Operation, Administration, and Maintenance (OA&M)

The SSC Platform must include the necessary indicators to allow its adequate maintenance ensuring:

- **Preventive Maintenance**: Storage and assessment of relevant indicators for maintenance management. Generation of maintenance plans based on these data.
- **Corrective Maintenance** (Warning Management): Possibility to manage warnings or alarms and send messages, e-mails, SMS, and calls based on these.

6.3.8.2.6 Process control

The SSC Platform should allow the control of the execution of the following processes, whether internal or external:

- Analysis of consumption, alarms, trends, etc.
- Cost allocation
- Sustainability (efficient use of facilities, emissions, etc.)
- Optimization of processes and planning
- Quality control of public services by third parties
- Crisis room
- Generation of exploitation reports

6.3.8.2.7 Decision support

The SSC Platform should have tools to improve the resilience of the city and decision making such as:

- Simulation based on current and historical information.
- Assessment and execution of action plans in complex scenarios.
- Predictive analysis and city modelling.
- Data mining and statistical analysis.
- Integration with other BI systems and tools.

6.3.8.2.8 Dissemination of Public Information in real-time

The Platform must allow the information to be transmitted in an open, reliable and quality way, continuously and without interruptions, in a standard format to allow access to it from multiple devices. This information applies to scenarios such as:

- Final services for the citizen.

- Third-party applications (open data).
- Other public services and Administrations.
- Accountability (transparency).

6.3.2.8.9 Availability

This is one of the most critically important elements. The Platform must guarantee the operational continuity of the services it provides, which, in many cases, could require 24x7 operation and an availability level higher than 99.9 per cent.

Achieving these availability goals involves the adoption of redundant/fault-tolerant physical architectures in computing and storage, energy, and communications.

6.3.8.3 SSC Platform-layered model

City platforms have been designed under the paradigms described in the chapter on technological architecture's objective reference. City Platforms incorporate advanced functional blocks and different interoperability functions to integrate the existing city infrastructure and facilitate interoperability.

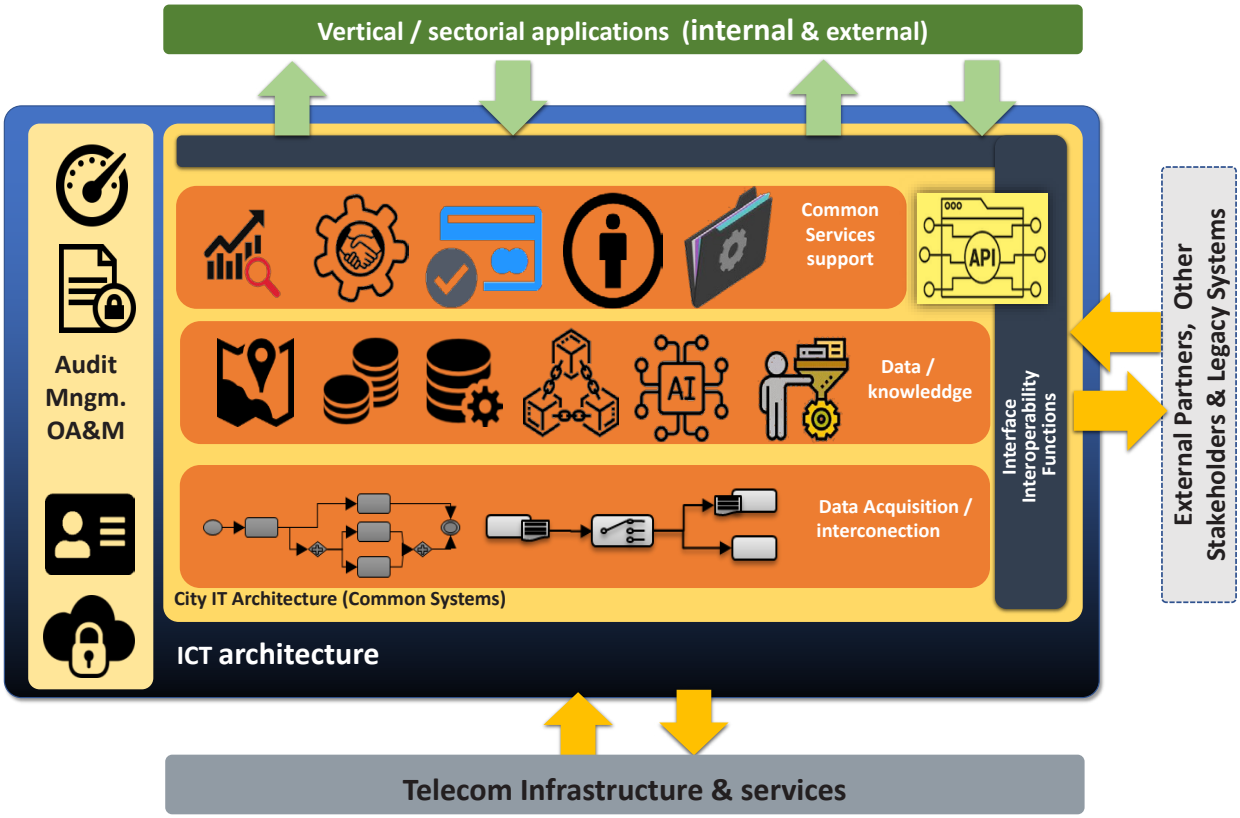
This model has been built as a multilayer architecture and is designed to meet interoperability requirements. For its development, several Smart and Sustainable Cities platforms existing today have been taken into account.

In this multilayer model, the elements that can comprise the Platform are described, leaving aside the infrastructure aspects, according to the following layers:

- Acquisition/interconnection
- Knowledge
- Interoperability
- Services
- Support

The infrastructure and communications of the elements in each layer, shown for information in *Figure 38*, have been referred to in previous paragraphs.

Figure 38: Smart City Platform layered model.



Communication between different layers and communication with third parties or other platforms is a key point displayed as arrows. Specifically, the key communications are:

- ***Services Interface***: Interface that joins the Service Layers with the Interoperability Layer. The interface connecting these two layers should be open and standardized. However, as long as there is no standardized interface, other interfaces can be used optionally. Therefore, in addition to the open and normalized APIs between these two layers, specific connectors in the Service Layer could provide specific services.
- ***Interoperability Interface***: Interface connecting the Interoperability and Knowledge Layers. The interface connecting these two layers must be open and standardized.
- ***Data/Metadata Collection Interface***: Interface connecting the Knowledge and Acquisition Layers: The interface connecting these two layers must be open and standardized.
    - The Acquisition/Interconnection Layer: Offers the mechanisms for the reception of data from the Capture Systems and is also responsible for allowing interconnection with other external systems that only consume data and, finally, abstracts the information from the Capture Systems with a semantic approach.

- The Knowledge Layer: Offers support for data processing, value incorporation and service transformation. It receives data from the Acquisition Layer (sensors) and the Interoperability Layer.
- Interoperability Layer: Facilitates the provision of services, offering open and standardized interfaces on the Knowledge Layer, establishing security policies and offering connectors so that external systems can access the Platform and vice versa. It also enables services to be built from the data of the Platform.
- Service Layer: These are services connected through the Interoperability Layer and the APIs provided. These applications may be running on the Platform or external services that publish or consume information.
- Support Layer: This transversal layer supports the rest of the functionalities offering services such as auditing, monitoring and security.
- Collection systems: Although they are not part of the Platform, they are formed by all the sensors/actuators managed by a city, for example, traffic lights, park irrigation, citizen devices (mobiles, etc.), external computer systems, and social networks.

6.3.8.3.1 Acquisition/Interconnection Layer

The Acquisition/Interconnection Layer is responsible for:

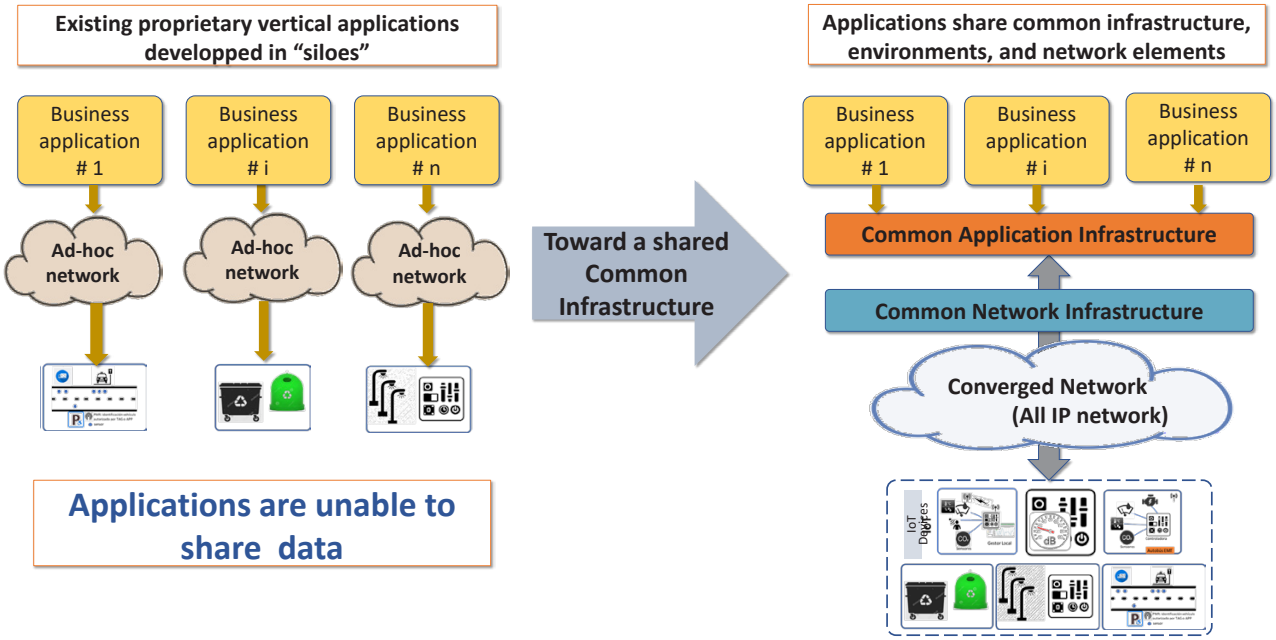
- Integrating information from data sources (Capture Systems), which can be:
  - From managed sensor networks, sensors, actuators, gateways, and devices such as traffic lights, buildings and weather stations.
  - Different devices such as people's mobile phones or devices in the home environment and vehicles, from public networks.
  - Social networks.
  - Other IT systems such as SCADAS or management solutions for vertical domains can be proprietary solutions.
- Providing the information to the Knowledge Layer regardless of the devices giving a semantic view of the acquired data, decoupled from the acquisition protocols.
- Independence of the network operator from the provision of network information and from its control.

Considering the Acquisition Layer of an ideal platform solution should conform to the principles of the M2M ETSI model:

- Open and standardized interfaces versus proprietary and closed interfaces, on which it will be possible to develop applications by third parties.

- The solution's modularity enables it to be deployed in parts simply, without necessarily making use of advanced processing and the capabilities of the Intelligence Layer.
- Unique Acquisition Layer, valid for different services.
- Independence of access technology and sensors. Compatibility of different access networks and M2M protocols.
- Open protocol support, protocol translation, or other solutions are required to make the platform independent of device complexity and allow access to sensors from different manufacturers.
- Ability to add new connectors when they are standardized.
- Access to platform sensors such as an event bus on which information from sensors and smart devices is accessed through the transport network.

Figure 39: Horizontal architecture model M2M ETSI (simplified)



6.3.8.3.2 Knowledge Layer

The Knowledge Layer contains the elements of treatment, management and exploitation of information, and is responsible for:

- Access to all historical and real-time information.
- Movement of data received from the acquisition layer, between the different functions of the Knowledge Layer for storage, processing and retrieval, and towards the Interoperability Layer. The data in this layer are already abstracted from the devices that generated them and must be treatable following standard data models.

- Support real-time treatment of the data received from the Acquisition Layer through modules such as Complex Event Processor engines.
- Support Batch processing of data received through ETL processes machine learning.
- Support analytical treatment of data through, for example, BI processes.
- Support GIS treatment of the data received, allowing georeferencing, making geographical queries, etc.
- Security in data access, which user/role is accessing each data set is controlled.

6.3.8.3.3 Interoperability Layer

The Interoperability Layer facilitates the provision of services in the field of the Smart City by offering interfaces and functionalities such as the Development Kit and Open Data, which will be used to implement the services that will be delivered to customers:

- Publish APIs that can be consumed from the Service Layer; it would be interesting to include the concept of API Manager.
- Ability to interconnect between applications and between platforms.
- Access from the Platform to external services.
- Publish open data through an Open Data Portal/Repository.
- A Development Kit that includes SDKs and APIs allows Services to be built within the Service Layer.
- All this is with the security integrated into APIs, Development Kit, and Open Data access.
- Based on a set of standards-based APIs, the Interoperability Layer must guarantee the portability of applications between cities and between platforms so that a true ecosystem of applications with critical mass is created, which lowers the barrier of access to application developers.
- The APIs exposed by the Interoperability Layer will be accessible for the developer community to use, so following the general trend, it should be a REST API.
- APIs must support different data access modes, including Push mode (subscription and notification) and Pull method (request and response). Georeferenced queries should also be supported.
- The data access model offered by the API will be agnostic for the particular data model; however, to enable interoperability, it must use a transport format compatible with any existing model. It is recommended to follow the OneM2M model for reference.

6.3.8.3.4 Service Layer

The Service Layer covers business, value-added services and applications. It interacts with the Platform through the Interoperability Layer.

Among the services that the Platform can support are:

- Custom Command Centres for different deployment locations based on user profile and permissions.
- Vertical service management applications such as Mobility, Energy Efficiency and Smart Irrigation.
- Integrated contract management applications, including SLAs based on real data. This includes functionalities such as:
    - Dashboard and indicators
    - Prediction, simulation, and planning systems.
    - Data processing system.

Smart Cities applications involve sectors such as:

- Energy and environmental sustainability
- Management of public buildings and other urban infrastructures
- Transport and mobility
- Commerce
- Safety
- City government and relationship with citizens
- Education, culture
- Tourism
- Leisure
- In the case of integration with a tourism information system, development of specific websites, apps and landing pages would be crucial. These platforms will be fed by any external and in-house systems providing key data such as demographics, expenditure, destination perception, business and activity forecasts, occupancy rates and mobility.
- Endnote: Potential external and in-house systems for the acquisition and distribution of key data are sensors, actuators and beacons, surveys, evaluations and opinions, and sustainability and SDG compliance indicators.

6.3.8.3.5 Support Layer

The Support Layer works transversally, supporting the other functionalities offering services such as auditing, monitoring and security.

- Repository of the Platform's configuration so that there is a centralized place of storage of all this.
- Web Environment of Configuration Management allows the management of all this through a Web application, including REST management interfaces.
- Connectors with Security Repositories to delegate platform security to the City User Manager (LDAP).

6.3.8.3.6 SC Platform Metrics

The metrics of the SSC Platform allow the capabilities of a Platform to be assessed qualitatively (and not quantitatively) in a global way.

- Degree of adaptation to the model of layers and functionalities of the Platform model for the operation of city services.
- The modularity of the Platform: Ability to install specific modules at an initial time and expand components and extend functionalities.
- Integration with other Platforms: Ability to import or export data to other platforms.
- Based on open standards: The entire Platform must be based on open standards, guaranteeing scalability and modularity. Within this criterion, open-source and commercial platforms can fit.
- Supported IoT protocols: Must be based on standard protocols and technologies versus proprietary technologies.
- Extension capacity of the Platform: In this area, the technology changes very quickly, so the Platform must be able to extend to add new capabilities protocols.
- Support a Big Data approach in a Smart City; a massive volume of data is generated, so this support is essential as it can evaluate, at this point, aspects such as the differentiation between real-time and historical data or Hadoop support.
- Support Open Data approach: The Platform must include access to Open Data according to open standards. Metrics should evaluate, for example, aspects such as support for standards such as RDF, oData, XM, or the use of products such as CKAN.
- The Platform could provide service in an on-premises and/or cloud model, depending on the client's requirements. Metrics may include the assessment of Support for the standards-based Cloud approach.
- The inclusion of GIS capabilities allows georeferencing of the information and consulting and representing this information.

- Inclusion of tools that allow working with the Platform simply and productively and configuring it.
- Availability and service level levels: RTO (Recovery Time Objective), RPO (Recovery Point Objective), and other parameters that may be considered.
- Guarantee, support, and roadmap of the Platform to ensure the present and future productive use.

6.3.8.4 City Platform Implementation use case

Although the actual implementation of the architecture of a City Platform is dependent on the manufacturer/integrator, many of them have designed their solutions based on a layer model very similar to that described in the previous section. In the specific case of the Platform of the City of Valencia (Spain), the architecture has been based on the FIWARE[49] framework.

FIWARE is a platform driven by the European Union for the global development and deployment of Future Internet applications. FIWARE provide a fully open, public and free architecture, as well as a set of specifications that allow developers, service providers, companies and other organizations to develop products that meet their needs while remaining open and innovative.

FIWARE has been adopted by the European Union initiative, Connecting Europe Facilities, as the key component for data management (Context Broker). Applications of this component lead the applications of Open Data, Data Lakes, and context managers.

The greatest differential value of FIWARE with respect to other initiatives are:

- 100 per cent Open-Source standard.
- Open data models and free use of licences, with mass adoption.
- APIs standardized by the WCO and ETSI through the ETSI NGSI-LD standard.
- Adoption by more than 250 cities in the world.

FIWARE is not about "taking all or nothing". You are not forced to use these complementary FIWARE Generic Enablers but are free to combine them with other third-platform components to design the hybrid platform of your choice. As long as it uses the FIWARE Context Broker technology to manage context information, your platform can be labelled as "Powered by FIWARE", and solutions build on top as well. Listings of many FIWARE Ready devices and commercial "Powered by FIWARE" solutions can be found on the FIWARE Marketplace.

The FIWARE architecture model coincides almost entirely with the one described in the section *6.3.8.3 SSC Platform-layered model* and has the following layers:

- Acquisition/interconnection
- Knowledge

- Interoperability
- Services
- Support

Figure 40 and the following sections describe the software components used in the City Platform, called *"VLCi Platform"*, for each of the layers, and although most of these are based on open-source software, municipal geographic information systems are based on solutions from the manufacturer ESRI.

In the following sections, the components used in the VLCi Platform in each of the described layers are listed in a very summarized way.

Figure 40: VLCi's City Platform implementation

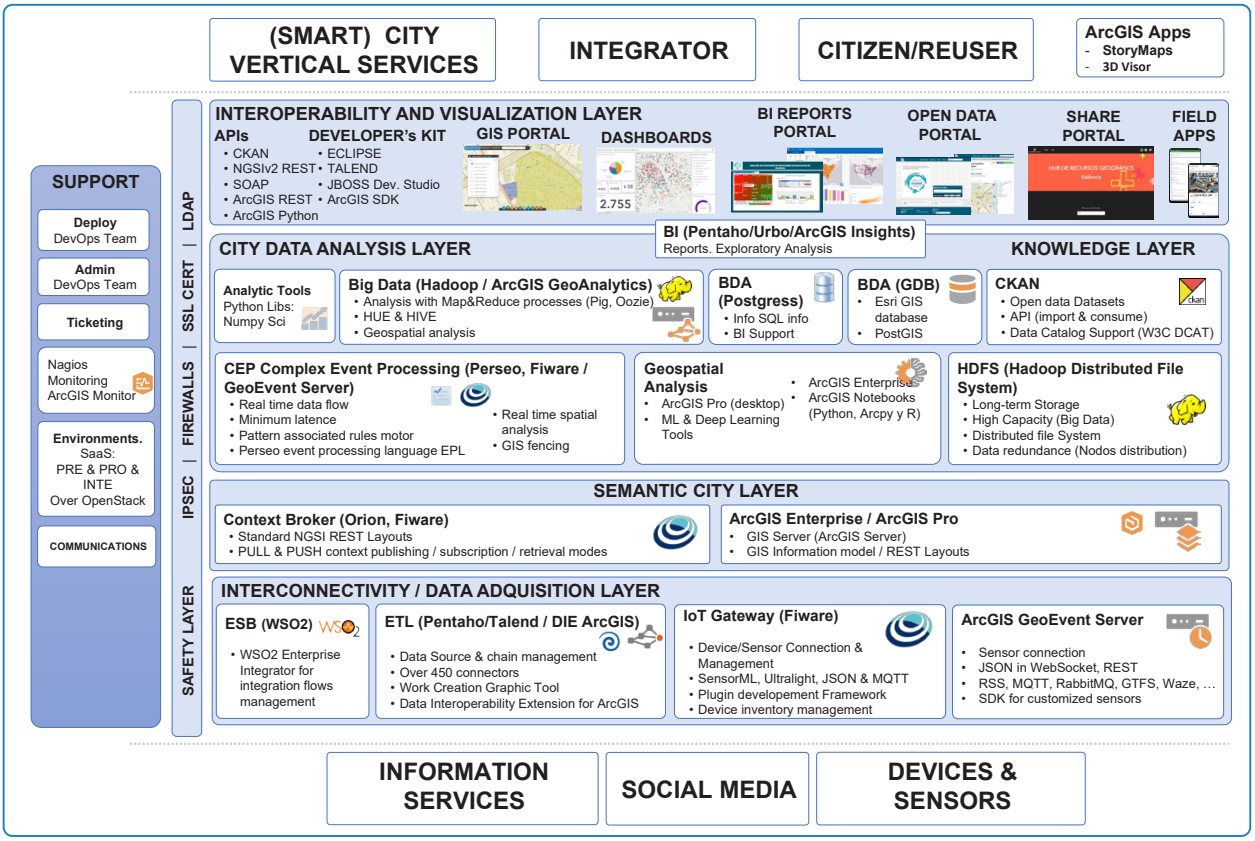


Table 3: Interconnectivity / data acquisition layer

Interconnectivity / data acquisition layer	
ESB (WSO2/Jboss FUSE)	• WSO2 Enterprise Integrator for integration flows management. • Framework integration. • Jboss Developer Studio.
ETL (Pentaho/Talend / DIE ArcGIS)	• Data Source & chain management. • Connectors. • Work Creation Graphic Tool. • Data Interoperability Extension for ArcGIS.
IoT Gateway (FIWARE)	• Device/Sensor Connection & Management • SensorML, Ultralight, JSON & MQTT • Plugin development Framework • Device inventory management
ArcGIS GeoEvent Server	• Sensor connection • JSON in WebSocket, REST • RSS, MQTT, RabbitMQ, GTFS, Waze, … • SDK for customized sensor

Table 4: Semantic city layer

Semantic city layer	
Context Broker (Orion, FIWARE)	• Standard NGSI REST interfaces. • PULL & PUSH context publishing / subscription / retrieval modes.
ArcGIS Enterprise / ArcGIS Pro	• GIS Server (ArcGIS Server) • GIS information model / REST interfaces

Table 5: City data analysis layer/knowledge layer

City data analysis layer/knowledge layer	
CEP (Perseo Fiware / GeoEvent Server)	• Real-time data flows. • Rules engine. • GeoFencing. • Spatial real-time analysis
Analytic Tools	• Python Libs: Numpy Sci
GeoSpatial analytics	• ArcGIS Pro (desktop). • Machine & deep learning
Big Data (Hadoop / ArcGIS GeoAnalytics)	• Analysis with Map&Reduce processes (Pig, Oozie). • HUE & HIVE. • Geospatial analysis

Table 5: City data analysis layer/knowledge layer (continued)

City data analysis layer/knowledge layer	
BDA (Postgress)	• Info SQL info • BI Support
BDA (GDB)	• Esri GIS database • PostGIS
CKAN	• Open data Datasets • API (import & consume) • Data Catalogue Support (W3C DCAT)
BI (Pentaho/Urbo/ArcGIS Insights)	• Reports. Exploratory Analysis

Table 6: Interoperability and visualization layer

Interoperability and visualization layer		
APIs	• CKAN • NGSIv2 REST • SOAP	• ArcGIS REST • ArcGIS Python
Developer's Kit	• ECLIPSE • TALEND	• JBOSS Dev. Studio • ArcGIS SDK
Dashboards & Portals	• GIS portal • Open data portal	• Collaboration portal • Bi reports portal
ArcGIS Apps	• Field apps • Story Maps	• 3-D Visor • ArcGIS Apps

Table 7: Safety Layer

Safety Layer
IPSEC
Firewall
SSL Certificates
LDAP

Table 8: Support Layer

Support Layer	
Deploy	• DevOps Team
Admin	• DevOps Team
Ticketing	• N/A
Nagios Monitoring	• N/A
ArcGis Monitor	• N/A
Development Environments SaaS	• PRE & PRO & INTE over OpenStack

6.4 ICT Governance – life cycle & processes

Management would focus on managing and implementing strategies on a day-to-day basis, while the government would be responsible for setting such strategies along with the politics and culture of the organization.

The implementation of IT governance is determined by different circumstances (Kordel, 2004) such as:

- The ethics and culture of the organization and the sector to which it belongs.
- Laws, regulations and action guides, internal and external.
- The mission, vision and values of the organization.
- Organizational models related to roles and responsibilities.
- The governance policies and practices of the organization and industry.
- The business plan and strategic purposes of the organization.

Every city should have an ICT Strategy Committee with at least the following functions:

1. Establish the strategic lines, in accordance with the policy established by the government, in ICT matters, for the promotion of the Digital Administration in the City Council and its public bodies.
2. Approve the proposal of ICT Strategy for its elevation to the Councillor responsible for the competences in Electronic Administration/ICT.
3. Inform the ordinances and other normative of general scope that is submitted to it by the proposing bodies whose object is the regulation in ICT matters, or of the resources of material and human nature affected by its development.
4. Define investment priorities in ICT matters in accordance with the objectives established by the government.
5. Declare the shared means or services.
6. Declare the projects of priority interest at the proposal of the delegations and their public bodies after a report from the ICT Service. Projects of priority interest will be those that, due to their special characteristics, are essential for improving the provision of services to citizens.
7. Promote collaboration and cooperation with other cities and entities for the implementation of integrated inter-administrative services and the sharing of technical infrastructures and common services that allow the rationalization of ICT resources.
8. Act as an Observatory of Electronic Administration and Digital Transformation.
9. The cities will need a Commission of Digital Administration. These collegiate bodies of departmental are responsible for the promotion and internal coordination in each department

in the field of Digital Administration. They will be the liaison bodies with the IT Service and the ICT Strategic Commission.

The Commission will study and plan the functional needs of the different administrative areas, assess the possible ways of action, prioritize them, and propose their development, all the time avoiding duplication, following the principle of rationalization, and promoting the sharing of common infrastructures and services.

Composition of the Commission:

- Head of Projects and/or Electronic Administration Section.
- Project Managers of the IT Service in the corresponding government area.
- Business Managers to decide.

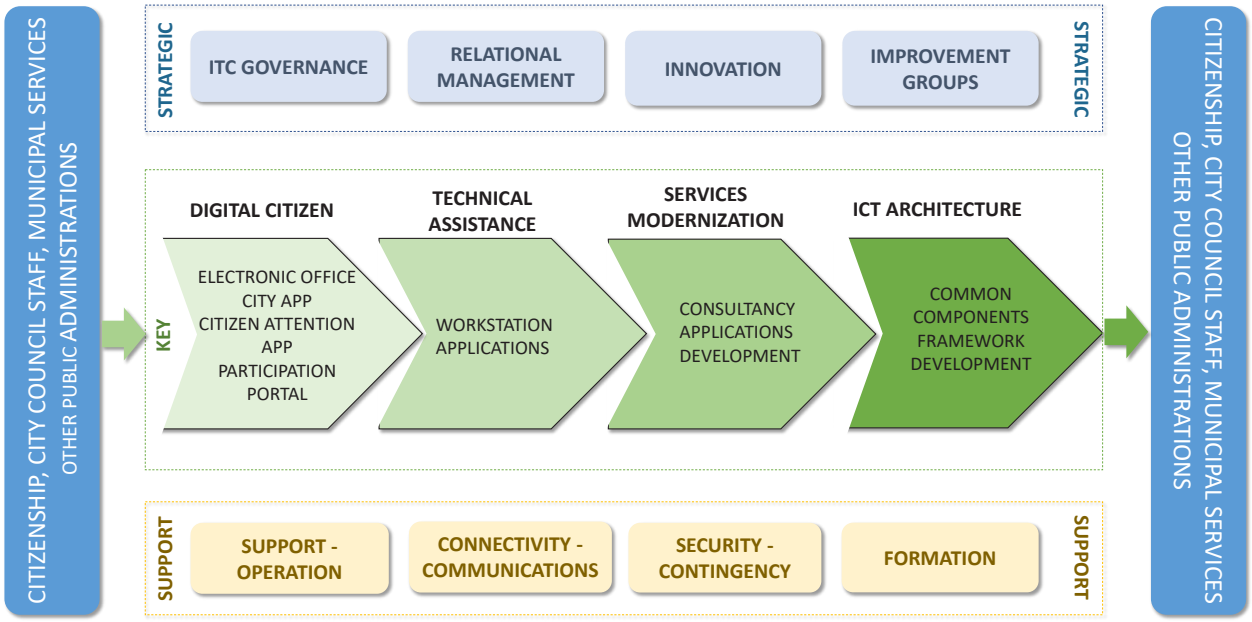
The organization must also match ICT projects to budgetary times.

Figure 41: ICT project life cycle

It is important that an ICT department generates certainty to the management services about how and when their complex needs will be addressed. The requests for ICT solutions must be compatible with the available ICT infrastructure and must be prioritized and endowed with a budget to be developed with own resources or through public tender.

A city must make a process diagram of its ICT service; although each city is different, the next flow of macro processes of an ICT service can serve in a majority of cities.

Figure 42: ICT macro-processes



This diagram identifies the main actors that are the origin and destination of the ICT services offered, and we can structure them into: citizenship, City Council staff, municipal services and other administrations.

There are several processes that can be considered transversal, supporting the provision of the key services of the ICT unit, which are the following:

- Support and operation of all information systems and ICT support infrastructures of the city.
- Connectivity and communications with a vocation for full coverage in buildings and in public spaces. A basic process to offer inclusive and homogeneous digital services throughout the territory.
- Training, taking into particular account the management of the change that the introduction of ICT produces within the organization and citizenship, which requires continuous training.

In the key processes section, processes related to the alignment of ICT as support to the business are identified, as well as other processes related to the efficiency in the provision of such services. Thus, we can identify, in a generic way:

- Digital citizenship: Understood in a broad sense as the set of ICT services that are provided directly to citizens, companies and services of the organization. Among them, as a minimum,

they should have solutions for an electronic headquarters, a citizen participation portal, open government, citizen attention, city app, and web.

- Modernization of municipal services in relation to digital transformation consulting, support in the development of applications to offer or supervise the services to be provided to citizens, with special attention paid to the creation of a city data infrastructure, as a transversal element on which to pivot the dashboards to support the strategic and operational decision making of the city.
- Technical assistance in the workplace, as well as in the information systems to support the management of municipal services.
- The core of any ICT service in a city is to constitute a robust, scalable and interoperable service-oriented ICT architecture that orchestrates the organization's common ICT services with the different ICT components of the municipal and external areas in a secure and privacy-preserving environment.

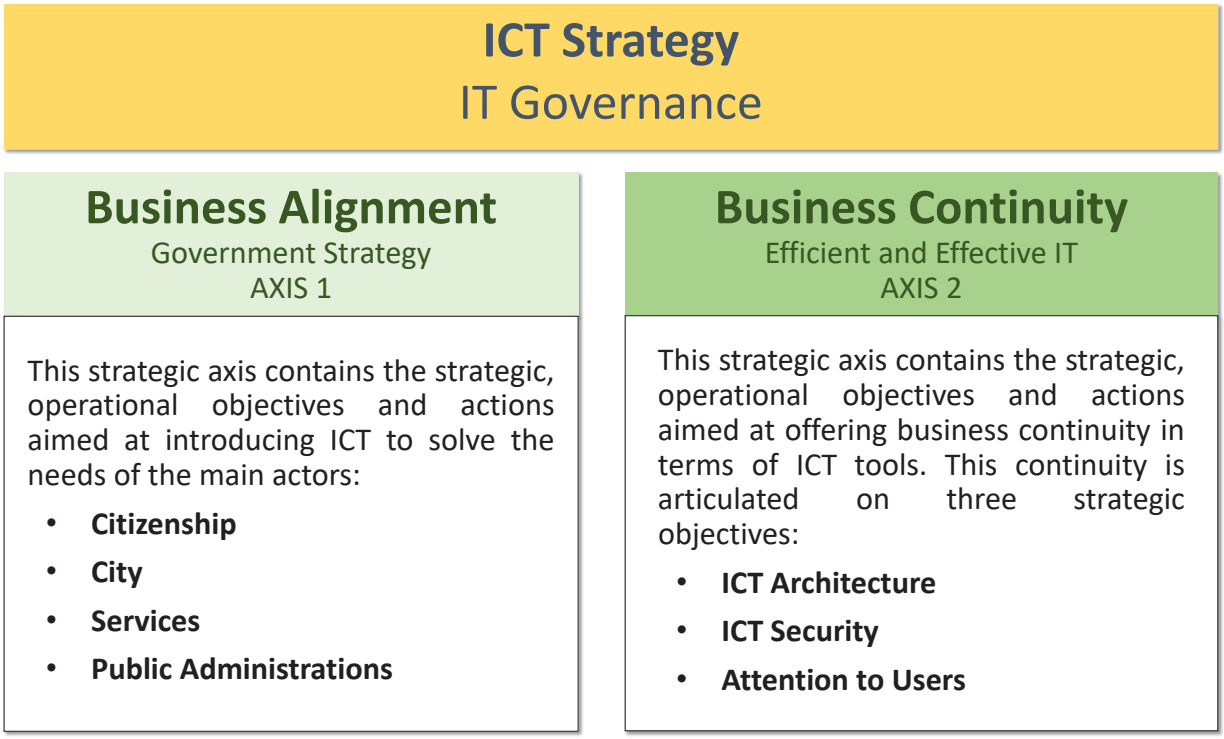
Each city has a normative, technological and human and economic resources reality; in this sense, a series of key strategic processes are identified for the effective management of this reality:

- ICT governance: A holistic and strategic vision that enables the building and maintaining of the key processes, taking into account the reality of the city in relation to the aforementioned regulatory, technological and resource aspects.
- The challenges of cities are increasingly complex, affecting not only multiple municipal areas but also the nearby socio-economic environment (e.g., universities, entrepreneurs, companies, NGOs), which requires a process of internal and external relational management.
- In the same context as above, the city must be an important element of the local innovation ecosystem. In addition, the process of managing missions must be supported with an adequate public ICT infrastructure so that each public or private element of the ecosystem allows an environment of attraction of talent and innovation.
- Collaboration between cities and between different public and private institutions to achieve common objectives requires the creation of interinstitutional and interdepartmental improvement groups in which ICT services must play an active role.

This chapter has started by defining ICT governance and the circumstances that can characterize it in a city environment. A possible organizational structure has been identified to address good management of IT, and the keys to aligning ICT needs to municipal budgets. As well as the definition of support, key and strategy macro-processes that all ICT services must face offering a service of excellence to the actors involved in these processes.

We could identify the main IT governance aspects of a city's ICT strategy in this environment.

Figure 43: ICT Strategy



This ICT strategy would contain the following axes and actions:

- Axis alignment with the government and the main milestones of sustainability and smart digitalization of the city, addressing strategic and operational aspects to introduce ICT to solve the needs of the main actors of the city: citizenship, city, municipal services, and other public administrations.
- Business Continuity Axis ensures that ICT services are provided effectively and efficiently in relation to ensuring business continuity and sustainable and robust growth. In this sense, there are three areas on which to develop actions: ICT Architecture, ICT Security and Customer Service.

The following graphs represent some of the actions to be developed in each of the seven strategic objectives:

Figure 44: Axis 1 Business Alignment

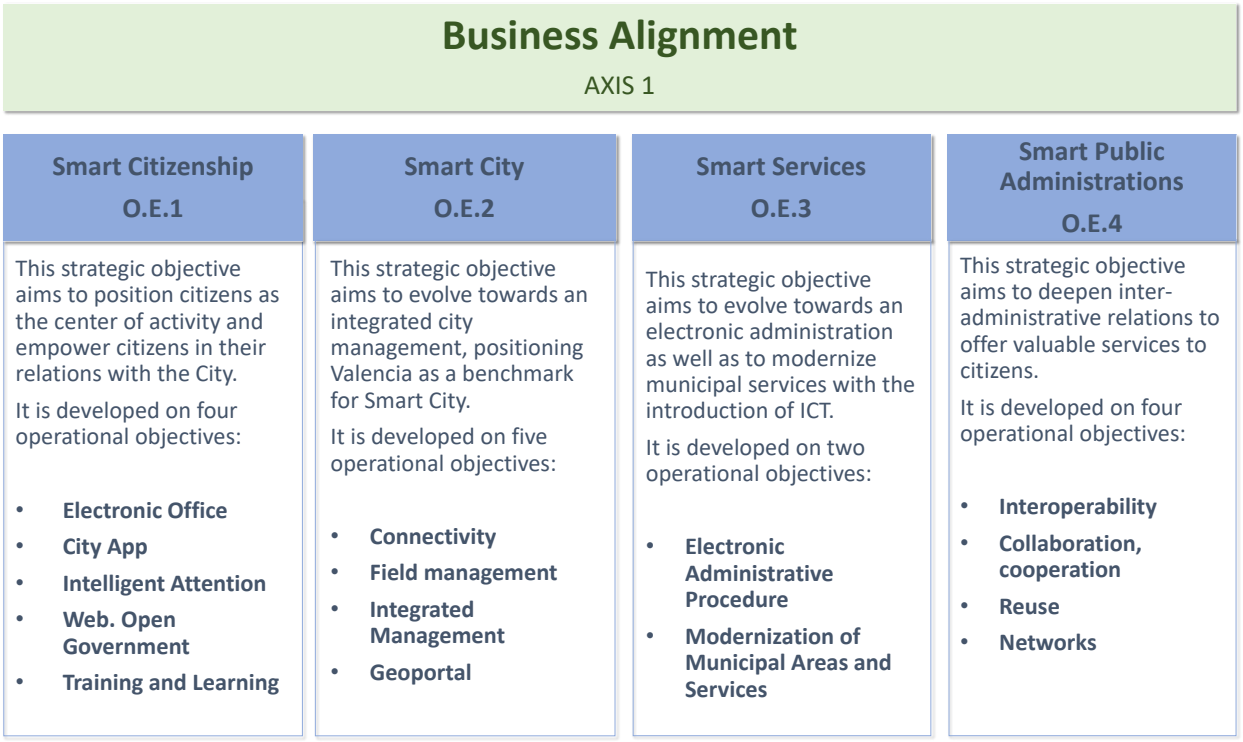
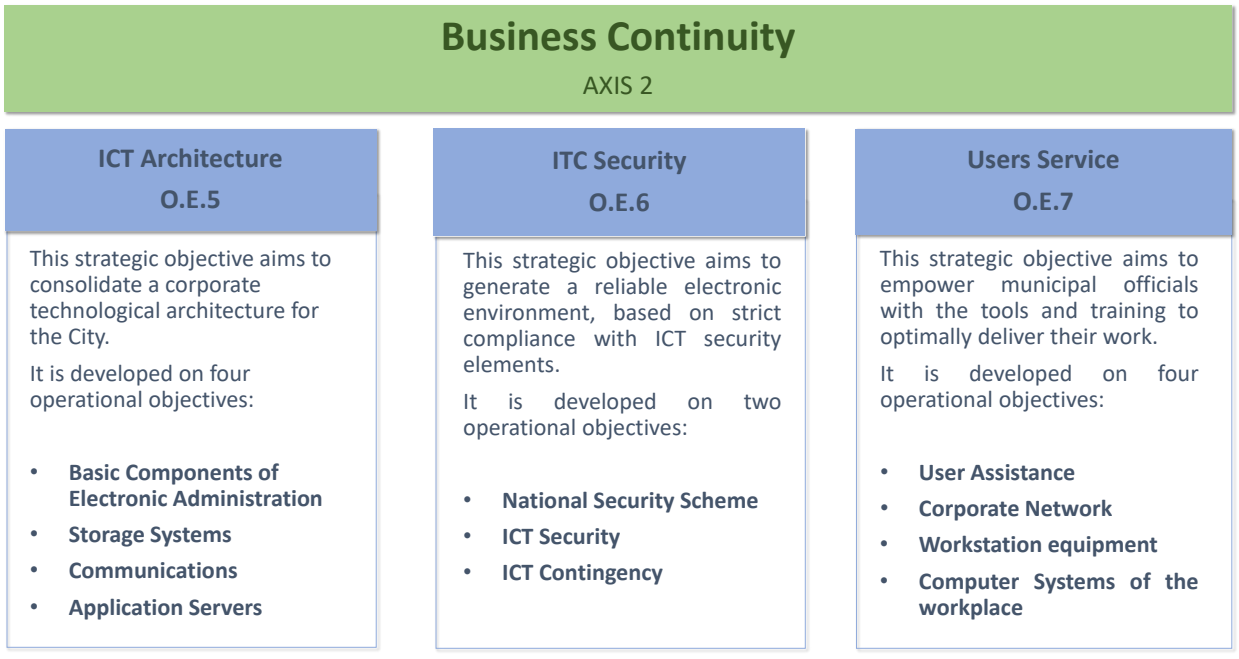


Figure 45: Axis 2 Business Alignment



7 Business and application components

Cities that are taking a "whole-of-government" approach to invest in digital infrastructure are best able to achieve economies of scale for building shared infrastructure that is available to the whole of the city and avoids duplication of investments.

This strategy, discussed in previous chapters, is also valid for the development of innovative and cost-efficient services and solutions to citizens, businesses, and the public sector. The proliferation of isolated solutions (silos) and the complex coordination between municipal departments cause inefficiencies, high costs, non-scalable solutions and difficulties in the re-use of code.

This chapter tries to answer the following questions:

- What are the principles of digital development?
- What are Building Blocks, and how can their technology help the agility and start-up of the components?
- What technologies offer a guide or model to build an integrated city or government platform, taking advantage of implementing the Digital Public Goods (DPGs) model?
- Why and How GovStack framework is relevant to Smart Sustainable City Reference Framework?

GovStack provides core digital components, i.e., Building Blocks, re-usable for cross-sector digital services. For example, let us consider the "Identity & verification" Building Block. The Identity & Verification Building Block creates, manages and uses a digital (foundational) identity. The Identity & Verification Building Block comprises a set of interoperable sub-components/modules dedicated to managing the legal/foundational national identity and its representation, offering different services for ensuring a trusted foundational identity and identification to the other GovStack Building Blocks.

As a use case, the reference to India's government enterprise architecture (IndEA) and National Urban Innovation Stack (NUIS) is shown.

7.1 Introduction

The IT ecosystem described in the previous chapter offers a pragmatic response to municipal operational needs. However, the development of new digital services for citizens represents a high cost, together with a definition of requirements that do not always cover all the objectives pursued, are complex to integrate into the municipal systems themselves, and do not adequately support possible future growth.

Cities that are taking a whole-of-government approach to investing in digital infrastructure are best able to achieve economies of scale for building shared infrastructure that is available to the whole of the city and avoid duplication of investments. This helps them focus on providing innovative services and solutions to citizens, businesses and the public sector. Investing in and adopting such an approach puts cities in a better position to deliver digital services at scale with a greater return on investment, as well as sustained citizen engagement.

In low-resource environments, this is an even greater need, since reducing costs, eliminating duplicate systems, and avoiding inefficiencies in coordination tasks can allow additional resources to be obtained to advance in the transformation and digitalization of the services provided to citizens, with the aim of achieving compliance with the Sustainable Development Goals (SDGs).

In developing complex applications, this model of Building Blocks can also be applied. A Building Block is an open and re-usable digital solution that can take the shape of a framework, a standard, software, software as a service (SaaS), or any combination thereof. Examples of this can be the blocks that offer services capable of electronically identifying users, creating and verifying an electronic signature, exchanging electronic data and means of payment, and so on.

Within the reference architecture described in chapters 4 & 6 on City Platforms, the **data-knowledge layer and the common services-support layer** allow functional blocks to be housed that can be used in the design of applications and digital services for citizens, generating efficiencies and cost savings. Database management, database processing, or geospatial management tools are examples of these.

The GovStack[50] initiative is an extension of the earlier effort established by the Digital Impact Alliance (DIAL) and the International Telecommunication Union (ITU) on the development of a normative logical framework called the SDG Digital Investment Framework.[51]

The GovStack initiative aims to build a common understanding and technical practice on fundamental re-usable and interoperable digital components, which we refer to collectively as "Building Blocks", to enable countries and cities to kick start their digital transformation journey by adopting, deploying, and scaling digital services. Through the digital "Building Blocks" approach, cities can easily create or modify their digital platforms, services and applications by also simplifying cost, time, and resource requirements.

In the following sections, the GovStack initiative, its architecture, the functional elements of which it is made up, as well as its evolution will be described in greater detail.

Also, an initiative in this regard has been developed by the European Union through the Connecting Europe Facility (CEF)[52] to support the Digital Single Market. In succeeding, the Digital Europe programme is funding a set of generic and re-usable Digital Service Infrastructures (DSI), also known as Building Blocks. The Building Blocks offer basic capabilities that can be re-used in any European project to facilitate the delivery of digital public services across borders and sectors. Currently, there are eight Building Blocks.[53]

The Building Blocks can be combined and used in projects in any domain or sector at the European, national or local level and have been designed based on:

- A Core Service Platform provided and maintained by the European Commission. Depending on the Building Block, the Core Service Platform may include technical specifications, sample software and supporting services (funding for the European Commission).
- Generic services in the form of Grants, supporting the Member States in the implementation of projects that re-use the Building Blocks (funding for the Member States).

From this advantage position, smart cities are also able to provide adjusted digital resources that incorporate tourists into the reality of citizens, which, from the urban scenario perspective, is in fact a shared reality. This dynamic involves the existence of public services consumed by two completely different individuals and, thus, touch points between them. The whole-of-government approach must consider these sensitive intersections in order to avoid an unpleasant citizen perception associated with over-tourism. All in all, the conception of a strategy considering tourism as an inherent phenomenon of the city, will lead to cross-cutting actions aimed at the improvement of the quality of life of residents, regardless of their tourist orientation. For this to take place, a four-step approach should be adopted:

1. Implication of stakeholders.
2. Identification of key tourism processes.
3. Consideration of tourism in the decision making and action taking processes.
4. Interpretation of the tourism impacts as city impacts.

7.2 Guidance with the Principles for Digital Development

The SDG Digital Investment Framework has defined four layers – SDG Targets, use cases, workflow, ICT Building Blocks (see *Figure 46*) – to help governments, cities and their partners take a whole-of-government approach to invest in shared digital infrastructure to strengthen SDG programming across sectors. This infrastructure has been designed under the following principles:

- **Neutrality**: We shall give no priority preference or exclusivity to a specific product or standard. All outputs and working processes will be based on how well it helps us achieve our goal.
- **Generic**: All knowledge products will be generic and comprehensive in capturing, as much as possible, all relevant design specifications and will not be specific to any single product in-market.
- **Open-source**: All final deliverables will all be open-source and publicly accessible for re-use and replication by anyone – they will be Digital Public Goods.
- **Standard-based**: All knowledge products will capture and be guided by industry-recognized standards – or re-use those from another sector where a lack of standards exists.

- **Minimalistic**: We shall focus on the most common functionalities at the lowest maturity level that is required to deliver the minimum capabilities for each Building Block.
- **Agile**: We shall use quick cycles to develop documentation to test and validate and then go for the next iteration.
- **Integration**: We shall ensure a seamless exchange of information across applications and deliver through different channels. Services should be "integrated by design".
- **Citizen-centric**: Design will be centred around typical high-priority user journeys and use cases related to the SDGs.
- **Secure**: Blocks are audited and certified before being made available; development processes and standards enforce quality and security; different certification levels reflect the level of standards-compliance; regular security scanning and auditing.
- **Accessible**: Meets users where they are: web, mobile, SMS and/or voice, SSO allows for signing in once for multiple services; shared ownership of code; deployment and development processes and standards are open to contributors; community-driven development tools for documentation and support; blueprints, templates and documentation.
- **Flexible and re-usable**: Blocks can be re-used in multiple contexts; each block is autonomous; blocks are interoperable; standardized configuration and communications protocols connecting blocks; blocks can be provided as a service (ICT opportunity).
- **Robust**: Operates in low-resource environments; occasional power; low bandwidth; low-reliability connectivity; easily scalable for high availability and reliability; API-only based decoupling; asynchronous communications pattern decoupled through rooms is ideal; eventual consistency for data.

7.3 GovStack Digital Government Platform Approach

A whole-of-government approach to developing government services through the re-use and minimal customization of quick and easy to adopt Building Blocks will address many of the current challenges by:

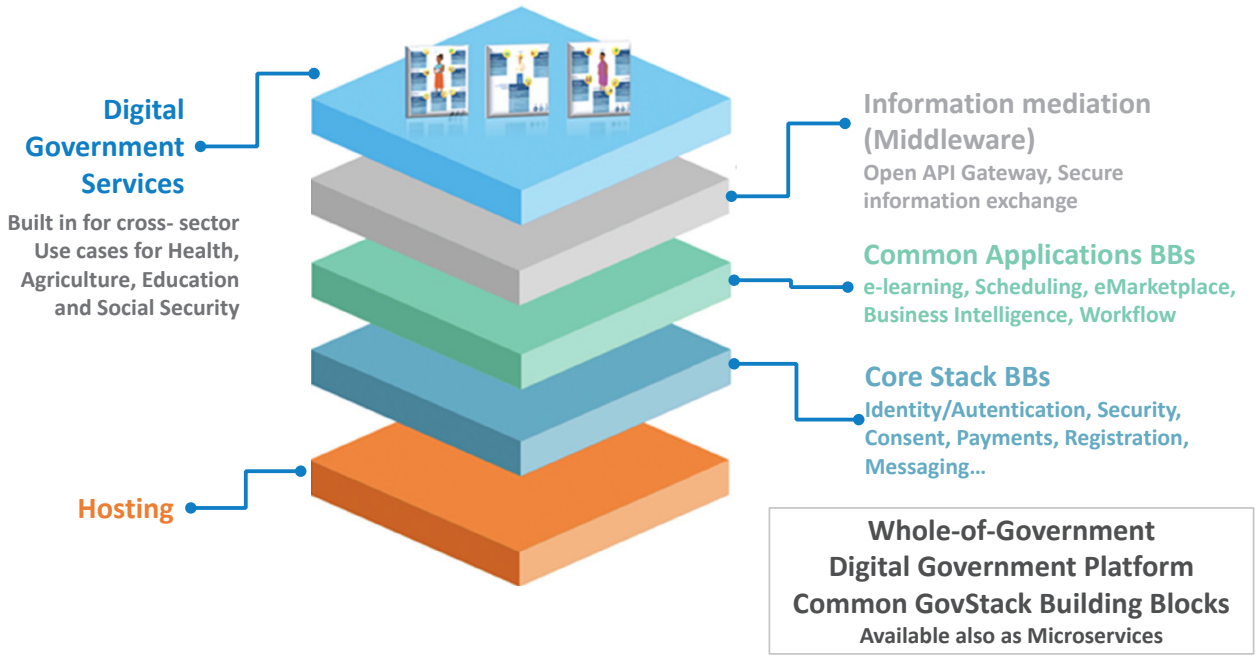
- Providing capabilities that are common across a range of departments and agencies in government and cities will avoid duplication and implementation of separate solutions that meet the same user need, reduce the time and cost to develop new solutions, and ease the maintenance of existing ones.
- Helping governments and cities to become more responsive, convenient, and user-focused.
- Enabling interoperability to integrate and exchange information easily with other platforms and systems through open standards and APIs.
- Enabling the development of new services by bundling and stitching re-usable Building Blocks through their APIs as opposed to building applications from scratch.

- Enabling exchanging data to deliver better value and experiences for users.
- Enabling aggregation of data for richer insights that would help develop policy and monitor operations.
- Avoiding technology "lock-in" and allowing services to run independently where Building Blocks could be upgraded or replaced without impacting the overall service.
- Ensuring compliance with security measures in place to meet legislative, regulatory and other requirements.
- Facilitating central maintenance of Building Blocks to ensure reliable and highly scalable services that will perform as expected, are accessible, and can scale to meet user demand.
- Enabling the development of services that can provide a connected, consistent, and seamless user experience.
- Increasing agility and responsiveness by having highly interoperable and flexible Building Blocks that are easy to adapt to changing needs, policies or legislation.
- Reducing costs and increasing speed of delivery by re-using and redirecting resources towards improving service delivery outcomes.
- Improving the ability of departments and agencies to build and deliver new services quickly and efficiently.

Digital platform that can be used by any government agency across sectors to build new eGov services without the need to redesign, test and operate the underlying systems and infrastructure themselves every time.

A WoG Digital Government Platform is a "platform of platforms" that can be used by any government agency, department across different sectors to build new government digital services.

Figure 46: WoG Digital Government Platform



Towards this direction, the working groups - formed by the stakeholders have conceptualized to develop 23 Building Blocks, which are categorized into types. Below is the indicative list of types and names of Building Blocks supported by a hosting or private cloud:

- **Foundational Blocks or Core Stack BBs**: Identity/Authentication, Security, Consent, Payment, Registration, Messaging, etc. Digital Public Infrastructure (DPIs) is considered part of this foundational layer.
- **Common Applications Blocks**: e-Learning, e-Marketplace, Scheduling, Business Intelligence / Analytics, Workflow…
- **Mediation middleware**: Open API Gateway, secure data information exchange.
- **Adaptive shared citizen-centric e-gov**: services facilitated by a service-oriented architecture.

Instead of creating unique and disparate solutions, use a common re-usable stack of Building Blocks to form the core platform engine and contextualize various e-city services on top.

7.3.1 Digital Government Platform Benefits

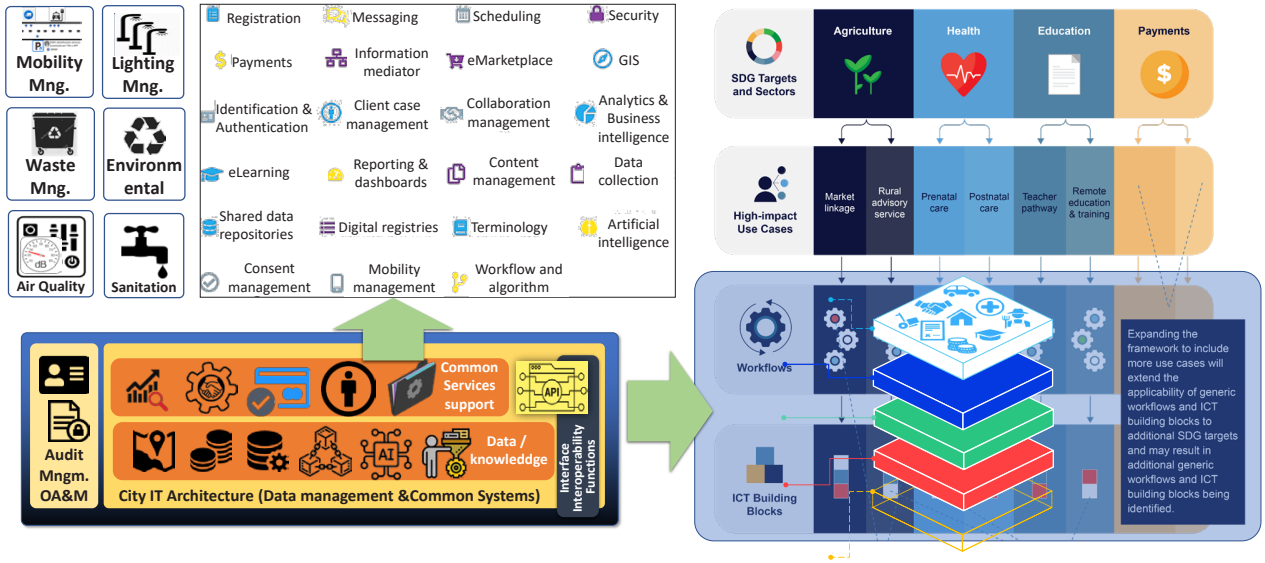
In summary, the deployment of this whole-of-government structure affects:

- **Speed**: Increases speed of delivery by facilitating re-use of core service elements and redirecting resources towards improving citizen outcomes.

- **Cost-efficiency**: Provides common cross-department/cross-agency capabilities, which avoids duplication of efforts reduces the cost to develop new e-Government services.
- **Real economic return**: Provides socio-economic ROI by enabling faster and closer connections from the government to address the needs of citizens and businesses.
- **ONE Government**: Enables service delivery that links and invokes different parts of government, providing a connected, consistent and seamless user experience.
- **Agility + Responsiveness**: Enable governments to design and deliver new services quickly to respond to needs and unexpected circumstances (e.g., global pandemics and disasters).
- **Integration + exchange**: Enables integrated transactions and exchange of information across other equivalent stacks and systems through standards and open APIs.
- **Harmonized policies**: Opens possibilities for aggregation of Big Data for richer insights that would help develop better non-conflicting policies and monitor operations.
- **Minimized vendor lock-in:** Minimizes product "*lock-in*" and allows independent services to run where modular Building Blocks could be replaced without impacting the overall experience.

Figure 47 shows a general outline that relates the generic IT architecture of the city along with the GovStack reference model and SDG Digital Investment Framework. The four layers depicted: SDG Targets, Use Cases, Workflows, and ICT Building Blocks

Figure 47: City IT architecture & GovStack approach



7.4 GovStack software components (Building Blocks)

Building Blocks are software modules that can be deployed and combined in a standardized manner. Each Building Block can work independently. Building Blocks are composable, interoperable

software modules that can be used across a variety of use cases. They are standards-based, open-source and designed for scale.

Each block represents, as much as possible, the minimum required functionality (MVP) to do its job. This ensures that each block is usable and useful on its own and easily extensible to support a variety of use cases. A block is composed of domain-driven microservices, modelled as closely as possible on existing human roles and processes. This helps ensure that each block is as useful as possible in the real world.

Blocks exchange data using lightweight, human-readable data that can easily be extended where needed. Data models and APIs are described in a lightweight manner that's human-readable, allowing them to be easily and quickly understood and validated.

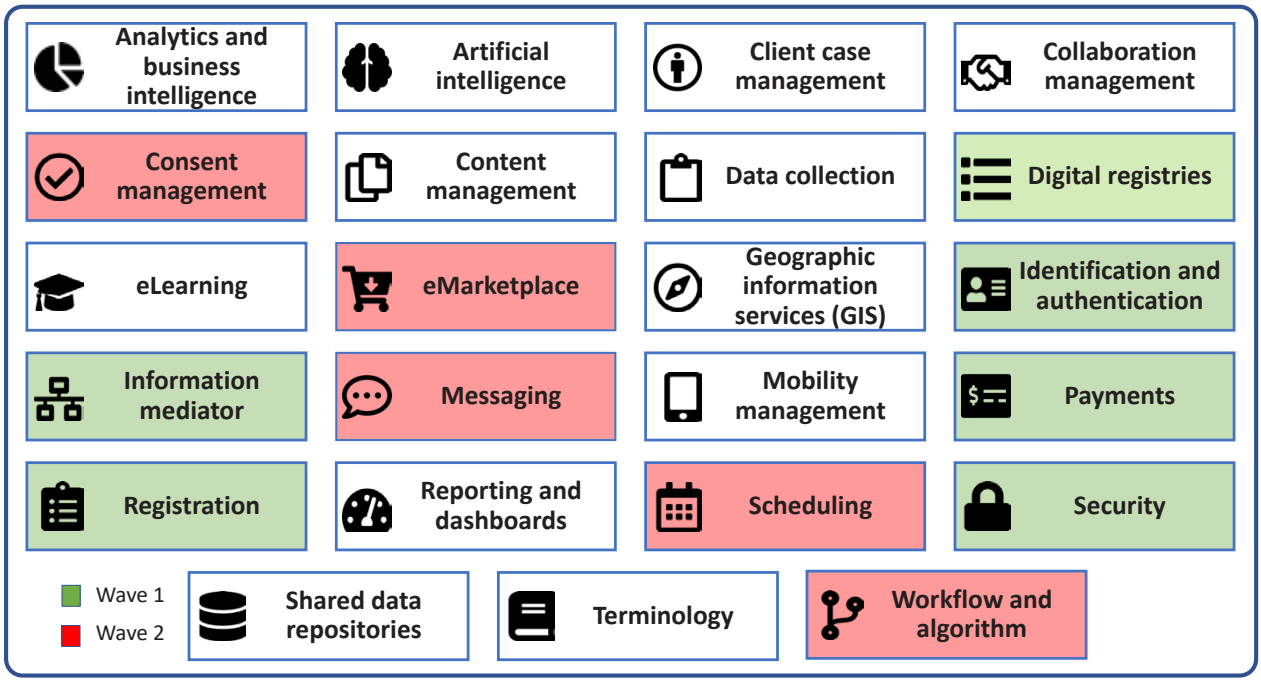
Building Blocks characteristics, in summary, are:

- Re-usable software components with very little or no modification. In the context of software engineering or the digital product development process, re-usability is the use of existing assets in some form within the software product development process; these assets are products and by-products of the software development life cycle and include code, software components, test suites, designs and documentation.
- Open-source, commercial off-the-shelf (COTS), or freely available with open access to data software licence is in its essence legally binding documentation for the use, adaption/modification, and distribution of a software product. Free and open-source software has fewer restrictions. Glossing over a lot of nuances, if a programme is released under a free software licence or an open-source licence, you do not have to ask anyone's permission to use it. You can also copy and modify the software.
- Facilitate one or more generic op. workflows. Workflows are associated with business processes that facilitate user interactions and execute applications according to a process map. Workflow services also provide a means to encapsulate existing applications, thereby supporting customer needs for leverage of existing assets.
- Applicable to use cases across multiple sectors. As the architecture progresses, the use case can evolve from the business level to include data, application, and technology details. Architectural business use cases can also be re-used in systems design work. An application use case diagram displays the relationships between consumers and providers of application services. Application services are consumed by actors or other application services and the application.
- Interoperable with other Building Blocks. Planning and developing a product with exposed interfaces compatible to current and future products and systems, without great recodification or add-on. To enable such a design and achieve an effortless environment for interchange or interaction, some form of exchange standards or set of interoperability standards is naturally introduced so all components follow one set of interface requirements and by which the standards will guide the format of transmission, transaction, and response among these components.

- Designed for Scalability. Scalability refers to the ability for a software product or its component(s) or node(s) to be replicated or deployed across fewer or more instances, e.g., physical or virtual locations. In the context of computer networks, this refers to horizontal scalability. This is largely driven by ensuring performance due to variance in volume of user activity, demand of specific function, or data traffic.
- Designed for Extensibility. Refers to vertical extension of functionalities of a product based on requirements and demand. This suggests the ability of a product to respond agilely to user needs and can expand on or reduce subscribed features or functionalities.
- Standards Based Conformance or Compliance. Standard conformance is defined as developing or certifying components to meet all normative requirements of the published standard. This is achieved through the definition of interface functions and information exchanges based on IEC, ISO, ISA, and other internationally recognized organizations that have a means of testing conformance.

Figure 48 shows the 23 defined Building Blocks. Development of these functional blocks has been carried out by prioritizing the core stack types (marked in green-wave 1). In wave 2, blocks marked in red, those related to common applications, are included.

Figure 48: GovStack Building Blocks



There are a total of 23 Building Blocks defined in GovStack, as listed below; each Smart City may choose a set of Building Blocks as per the needs of its citizens.

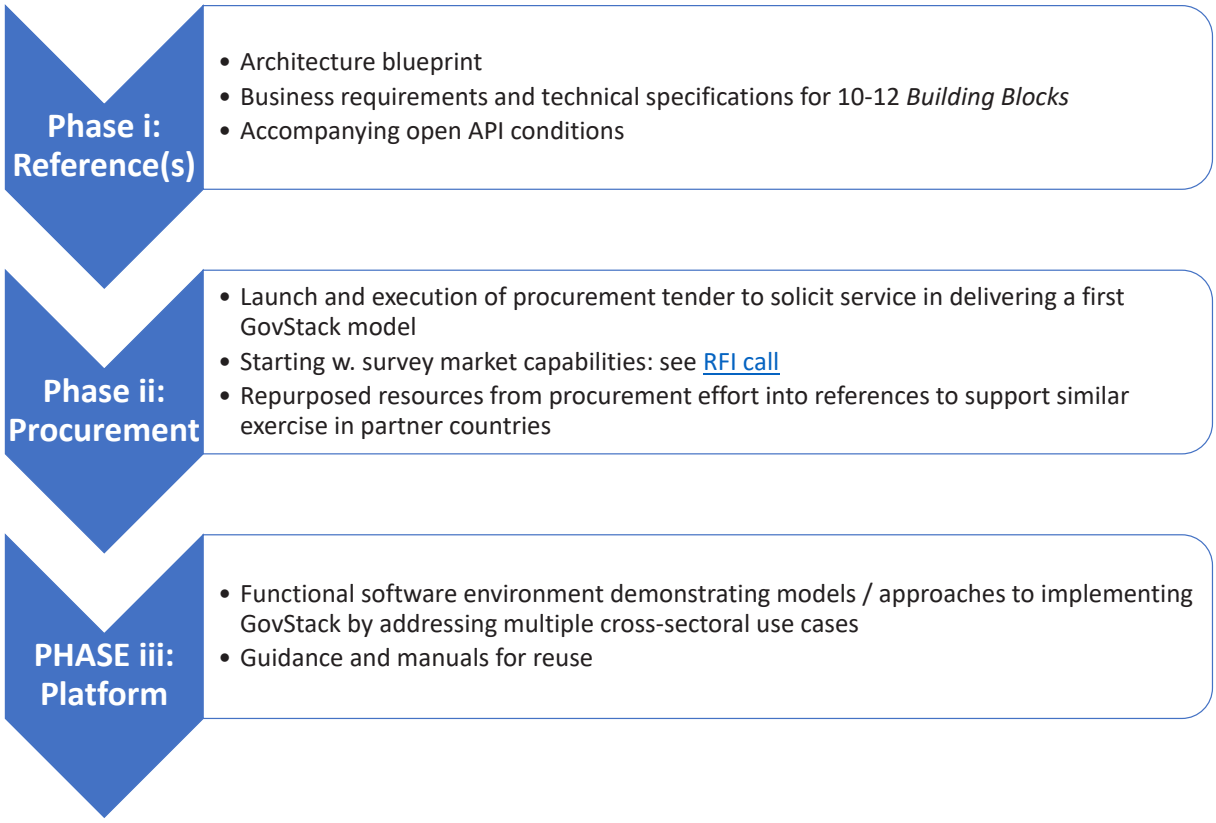
Table 9: List of GovStack Building Blocks available.

GovStack Building Blocks	
Analytics and Business Intelligence	Information Mediator
Artificial Intelligence	Messaging
Client Case Management	Mobility Management
Collaboration Management	Payments
Consent Management	Registration
Content Management	Reporting and Dashboards
Data Collection	Scheduling
Digital Registries	Security
eLearning	Shared Data Repositories
eMarketplace	Terminology
Geographic Information Services (GIS)	Workflow and Algorithm
Identification and Authentication	

7.5 GovStack Future activities

The Building Blocks, along with their functional and technical specifications, Open APIs, Open Standards will be used to develop an Open Architecture and Blueprint for model a "Digital Government Platform". A Mini Digital Government Platform Sandbox will also be developed for experimenting and demonstrating how a common GovStack can deliver a set of cross-sectoral interoperable, secure and integrated digital government services based on target use cases. Lastly, capacity building activities to raise the awareness of Digital Government Platform and GovStack will be undertaken.

Figure 49: GovStack Development Phases



7.6 A reference to India's government enterprise architecture, (IndEA) and National Urban Innovation Stack (NUIS)

In 2018, India published its government enterprise architecture, IndEA,[54] which applied the whole-of-government approach to delivering common public sector services.

Under the overarching vision of the Digital India Programme, the Government of India aims to make all government services digitally accessible in an integrated manner to citizens through multiple channels like web, mobile and common service delivery outlets. Also, users have become tech-savvy and now demand faster delivery of services that match those of private sector and other e-Governance-delivering nations across the world. The United Nations e-Governance survey emphasized a whole-of-government approach, policy integration and use of Big Data analytics to provide better governance to citizens. These trends require the breaking of sectoral barriers and silos and re-architecting the government as a single enterprise. Accordingly, a working group was constituted by Standardisation Testing and Quality Certification (STQC), MeitY to develop the India Enterprise Architecture (IndEA) framework.

IndEA provides a generic framework (based on The Open Group Architecture Framework – TOGAF) comprising of a set of architectural reference models, which can be converted into a Whole-of-

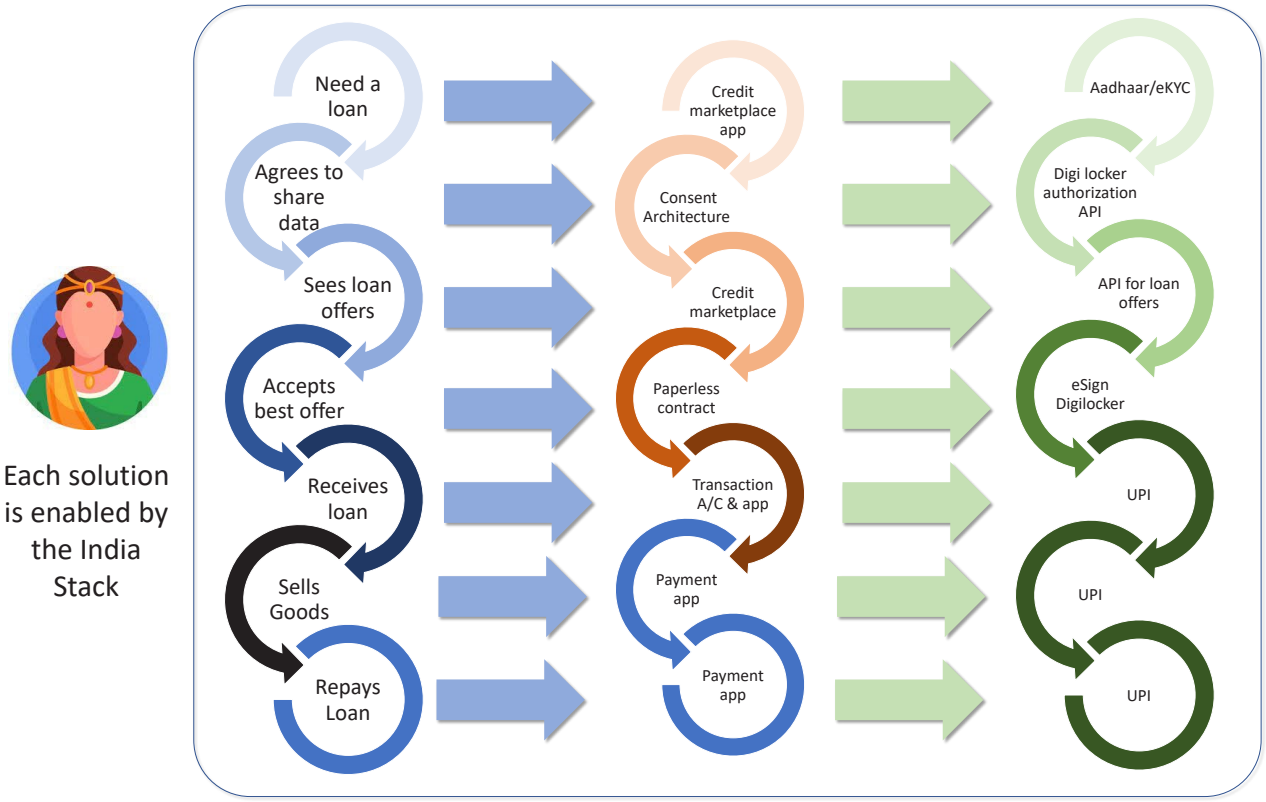
Government Architecture for India, including ministries, states and government agencies. The IndEA framework is based on a federated architecture approach and recognizes the need to accommodate greenfield (new) and brownfield (existing/legacy) eGovernance initiatives.

The IndEA framework guides investment into digital public goods, which in effect are centrally administered digital infrastructure and applications available to all sectors and facilitated by a set of Open APIs called "India Stack".[55] A prime example is India's national ID system (Aadhaar), with more than 1.2 billion subscribers.

Since its introduction, Aadhaar has stimulated the growth of India's digital economy, enabling digital payments of USD 57 billion and saving the government USD 13 billion in reduced transaction overheads.[56]

With a broad ubiquitous inclusive platform that has no physical presence required, costs are reduced in designing new services with already significant social outcomes, including rapid growth in bank account ownership, digital ID covering almost the entire population, and enhanced infrastructure reaching more mobile devices.[57]

Figure 50: India Stack framework



While IndEA has been notified as a standard framework for designing Enterprise Architectures, its adoption has been slow due to the challenges posed by the resource-intensive and time-taking nature inherent in designing Enterprise Architectures in a classical way.

To overcome these challenges, the Agile IndEA Framework[58] was developed by India's Ministry of Electronics & Information Technology. A pragmatic approach is adopted in the design, development and implementation of enterprise-class digital projects, keeping in view the triple constraints of scope, time and budget.

The IndEA Framework defines a "minimum viable architecture" model (MVA) that is designed in terms of Building Blocks. Building Blocks are categorized as Core Building Blocks (CBBs) and Common Solution Building Blocks (CSBBs). The CBBs represent the technical capabilities, while CSBBs capture the common business requirements.

Building Blocks can be categorized along these four types to facilitate designing the Logical Architecture of the system.

To overcome these challenges, the Agile IndEA Framework[59] was developed by India's Ministry of Electronics & Information Technology. A pragmatic approach is adopted in the design, development and implementation of enterprise-class digital projects, keeping in view the triple constraints of scope, time and budget.

Table 10: InDEA Building Blocks

Building Block	Type
Infrastructure BBs	Cloud, SoC, Enterprise App Store, Unified Call Centre.
Data BBs	Digital Identity, Digital Registries, Enterprise Directories.
Technology BBs	Gateways (Integration, Messaging), Mobility Management (MDM), Collaboration Management, Consent Management.
Application BBs	Analytics, Artificial Intelligence, e-Payments, Workflow, Case Management, Dashboard.

Table 11, provides a list of Agile IndEA Building Blocks, which have been categorized according to their category (CBBs or CSBBs) and development priorities (wave 1 & wave 2). Also, to align and sequence efforts in the most efficient manner, a phased development of waves has been defined.

Table 11: IndEA Catalogue of Building Blocks

Category	Agile IndEA Building Blocks
Core Building Blocks	**Core Building Blocks to be established in WAVE 1**
	1. **Digital identity** – Enable unique identification and authentication of users, organizations or other entities. 2. **Digital Registries** – Centrally manage databases that uniquely identify and describe persons, service providers, facilities, assets, procedures, products, sites or other entities related to the organization. 3. **Integration management** – Provide a gateway between external digital applications and other Building Blocks, thereby ensuring interoperability and implementation of standards, which is essential for integrating various Building Blocks and applications. 4. **Messaging** – Facilitate notifications, alerts, or two-way communications between applications and communications services, including short messaging service (SMS), unstructured supplementary service data (USSD), interactive voice response (IVR), e-mail or social media platforms. 5. **Cloud Infrastructure** – For hosting data and applications, getting all the benefits of cloud. 6. **Security and access** – Provide ICT administrators the ability to centrally configure and manage user and group access permissions to network resources, services, databases, applications, and user devices.
	Core Building Blocks to be established in WAVE 2
	1. **Mobility management** – Securely enable employee use and management of mobile devices and applications in a business context. 2. **Analytics and business intelligence** – Provide data-driven insights about business processes, performance and predictive modelling. 3. **Artificial intelligence** – Package machine intelligence capabilities as re-usable services to perform work, extract insights from data, or provide other business capabilities. 4. **Geographical information** – Provide functionality to identify, tag and analyse geographic locations of an object such as a water source, building, mobile phone or medical commodity. 5. **Enterprise App Store** – Provide a single touchpoint (download point) for all the apps of the Enterprise.

Table 11: IndEA Catalogue of Building Blocks (continued)

Category	Agile IndEA Building Blocks
Common Solution Building Blocks	**Common Solution Building Blocks to be established in WAVE 1**
	1. **Registration** – Records identifiers and other general information about a person, place or other entity, typically for registration or enrolment in specific services or programmes and tracking of that entity over time. 2. **E-Payments** – Implement and log financial transactions receipts and payments online in multiple ways. 3. **Workflow management** – Help to optimize business processes by specifying the rules that govern the execution of a sequence of activities and the exchange of associated information to orchestrate the process flow from initiation to completion. 4. **Case management** – Register or enrol users and provide longitudinal tracking of services, often across multiple service categories, departments and locations. 5. **Feedback** – Provide the ability for consumers and providers of services to send, track and address any issues pertaining to service quality, including any kind grievance redressal. 6. **Consent management** – Manage a set of policies allowing users to determine the information that will be accessible to specific information consumers, for which purpose, for how long, and whether it can be shared further. 7. **Reporting and dashboard** – Provide pre-packaged and custom presentations of data and summaries of an organization's pre-defined key performance metrics, often in a visual format.
	Common Solution Building Blocks to be established in WAVE 2
	1. **eLearning** – Support facilitated or remote learning through digital interaction between educators and students. 2. **Collaboration management** – Enable multiple users to simultaneously access, modify or contribute to a single activity such as content creation, through a unified access portal. 3. **Content management** – Support the creation, editing, publishing and management of digital media and other information. 4. **Scheduling** – Provide an engine for setting up events based on regular intervals or for triggering specific tasks in an automated business process, based on specific combinations of status of several parameters. 5. **Terminology** – Provide a registry of definitions and terms with defined nomenclature standards, metadata, synonyms and sometimes a knowledge map for a particular domain of knowledge (e.g., health), which can be used to facilitate semantic interoperability**.**

In 2019, the National Institute of Urban Affairs (NUIS)[60] was envisioned to act as a digital public good, in the form of a set of APIs or Building Blocks for all stakeholders across the "quadruple helix" of government, industry, academia, and civil society and citizens' groups in urban India. These Building Blocks will enable different stakeholders to collaboratively design, implement and refine innovative solutions to local problems. While traditional approaches to innovation focus on identifying and scaling solutions, NUIS aims one step higher: to build local, distributed and decentralized capacity to solve, and to do so at speed and scale. NUIS adopts a stack approach to provide adaptability and ease of adoption, envisioning a fractal pattern of platforms, each of which

is further made up of re-usable and modular Building Blocks arranged in various configurations as per the needs of each use case.

The NUIS is envisioned as a shared digital infrastructure that fosters innovation and collaboration in the ecosystem by unlocking the collective imagination to create novel solutions. The NUIS is predicated on the empowerment of people and enablement of processes in the ecosystem to drive solutions at scale and with speed.

The NUIS is a collection of cloud-based services. Each service efficiently provides a single capability across multiple urban services, accessible through using simple, open APIs compatible with global standards. In addition, it provides a set of open standards and specifications that enable the ecosystem players to innovate on the stack. Together, these services and standards create a powerful framework to drive convergence and a faster implementation cycle for any urban initiative.

The stack approach may facilitate the SSC by:

- Unbundling the challenge into micro problems such as need records of Identity & Verification.
- Arranging the micro problems into various layers based on how context-specific they are and identifying micro solutions for each such as data infrastructure layer, core service layer, urban solutions layer, and so on.
- Identifying the Building Blocks from the existing stack which can be leveraged such as Digital Identity, Payment Registries, Geographic Information Systems (GIS), eSign, etc.
- Use of principles, specifications and standards.

Referring to point (3) above, it is important to mention that IndEA has certain common public digital goods such as *Aadhaar* (Digital Identity; also read for "faceless" feature), Unified Payment Interface (for Payment registry; also read for "cashless" feature), DigiLocker (for documents; also read for "paperless"); and many more. These core digital goods will let NUIS customize its digital services to citizens.

To understand more, please refer to *Figure 51* and *Figure 52* below, which explains the role of Building Blocks. In *Figure 51*, the capabilities are rolled out with a specific roll-out of the programme. For example, "Smart Governance" indicated in orange will lay out "Trade licence" in Solutions, "User registry" in Core Data Infrastructure layer, and so on.

Figure 52 explicitly conveys how different Building Blocks have been used for each layer. Data Specifications Infrastructure, Common Registry Infrastructure, Data Encryption and Signing Infrastructure, Data Exchange Infrastructure are the key Building Blocks required in the Core Data Infrastructure layer. Similarly, Authentication, Authorization, Billing (demand and receipt generation), File management, Grievance management, Localization, Notifications, Reporting, Telemetry, Urban GIS, User management, Workflow management are the key Building Blocks required in the Core Services layer. Context/programme-specific components, priority-based Building Blocks are developed in the Urban Solution Platform.

Figure 51: Evolution of Urban Stack

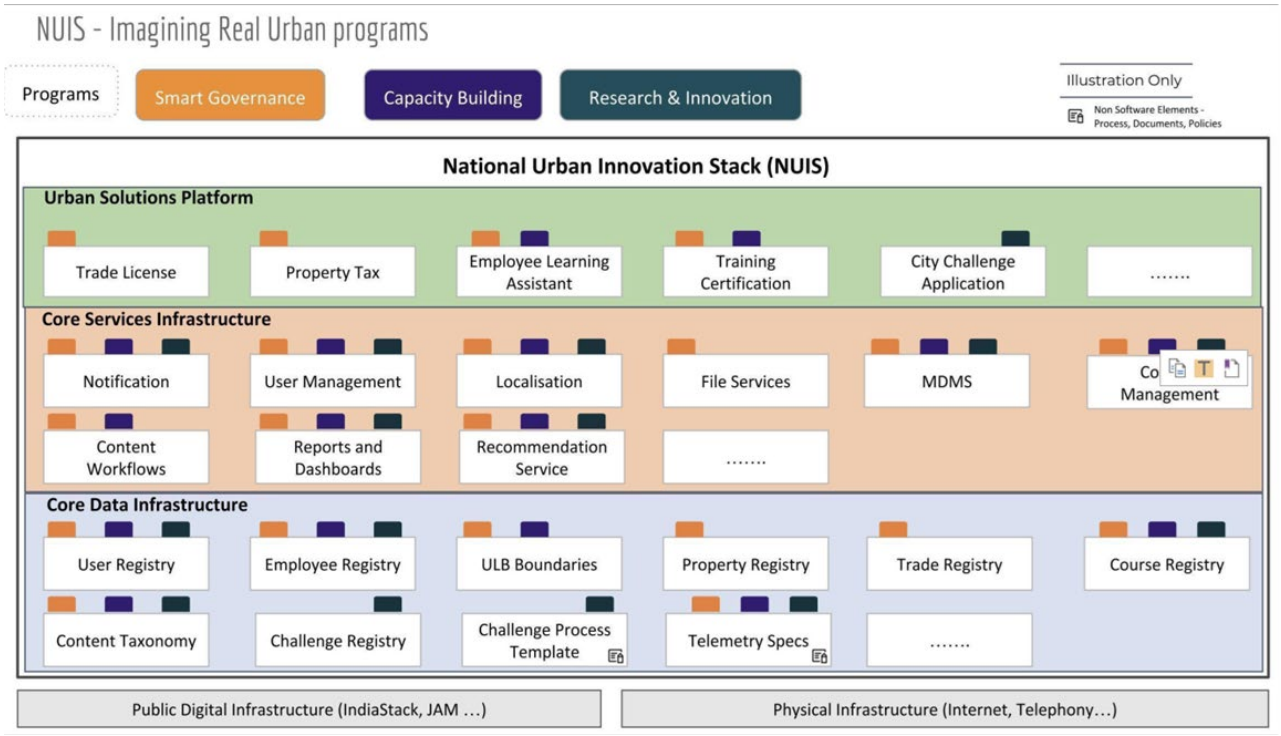


Figure 52: Enabling multiple programmes implementation through key infrastructure, services, and platforms.

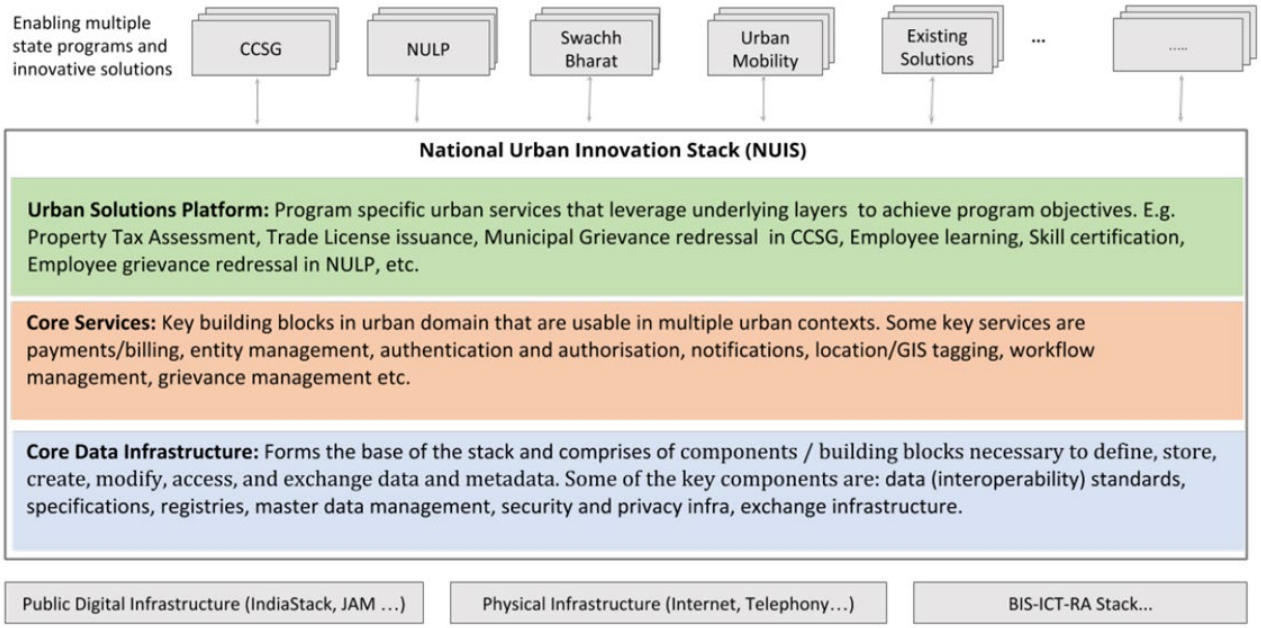
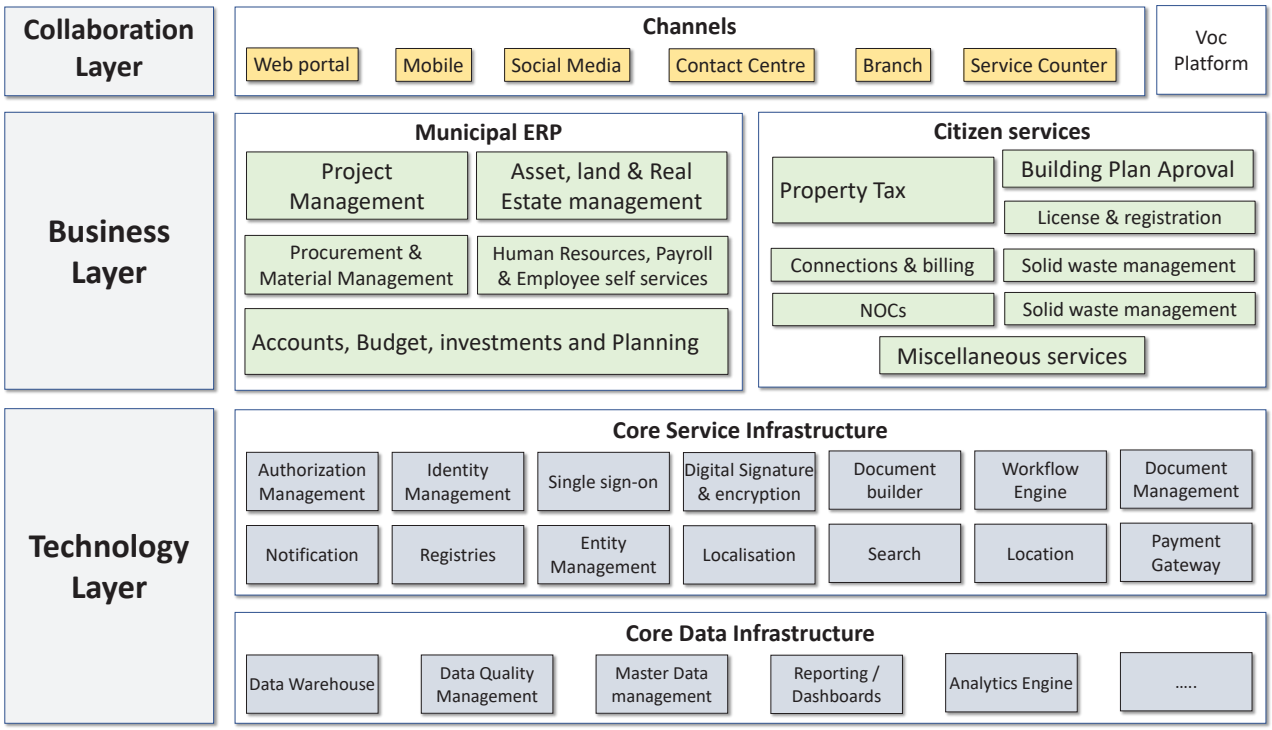


Figure 53 shows the reference architecture of the municipal governance model[61] proposed by the Bureau of Indian Standards.

Figure 53: High-level architecture of municipal governance System



Finally, one of the key programmes supported by the NUIS is India Urban Data Exchange (IUDX), which is described very briefly by the interest of describing a City Platform Architecture.

IUDX is being created as an open-source and collaborative effort, involving contributions and support from a wide variety of stakeholders in the industry, academia, and community organizations. A collaborative ecosystem ensures that this critical piece of national infrastructure is best-of-breed, responsive to the needs of cities and immune to being captured or controlled by a single commercial entity. The need for the IUDX is driven by the fact that, by nature, city data originates from a wide variety of sources.

Some of it consists of streams of IoT data from installed sensors (e.g., air quality, traffic), while other data are demographic or geographical. Some data may come from municipal tax or property records, while other data are derived from legal documents and registrations. A large amount of data is historical and derived from archival sources. Each set of data has its own security and privacy consideration, as well as commercial, monetary or subscription aspects, which must be observed. However, due to organizational inertia or friction or other reasons, the data often resides in several independent silos, without standardization of software components, their interfaces, or the underlying data models.

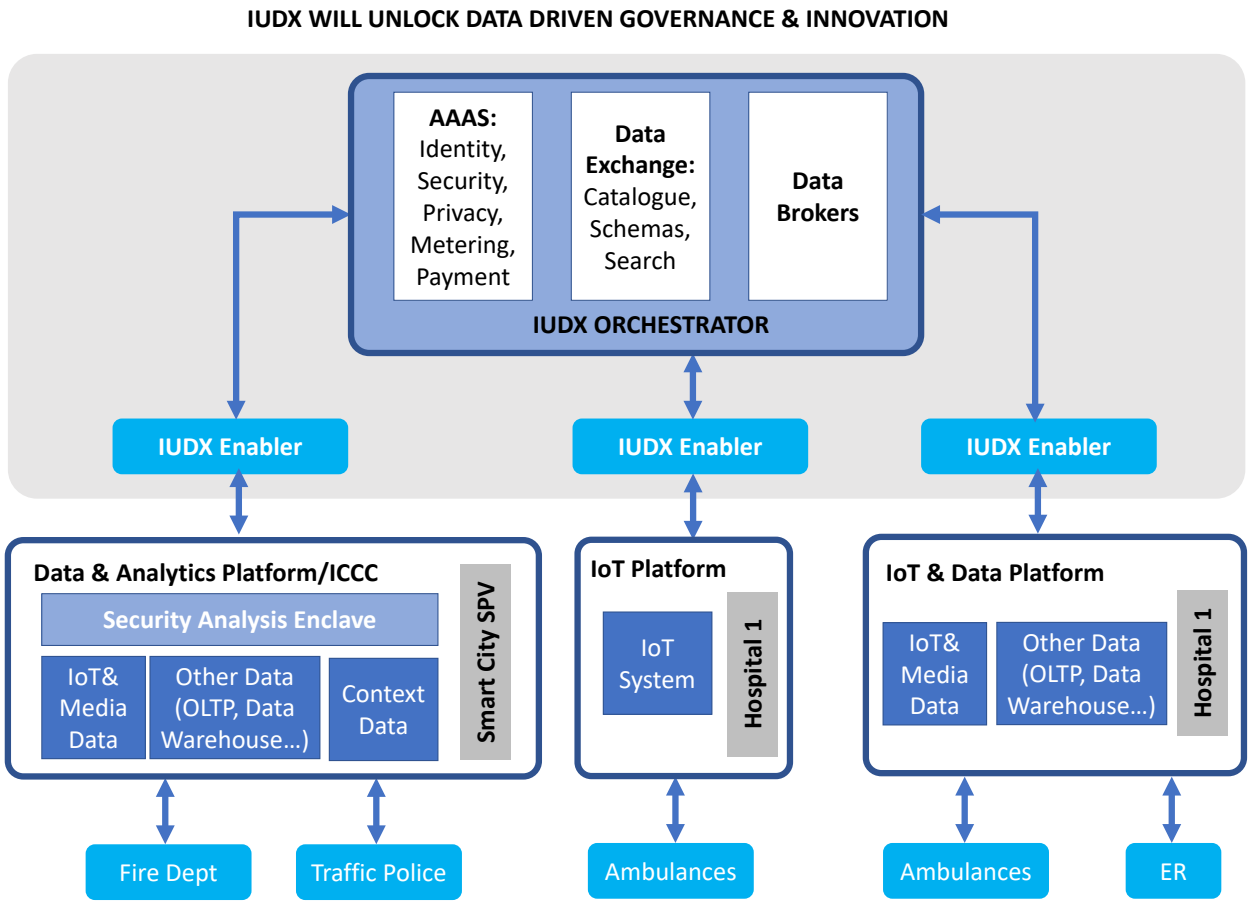
The IUDX is a win-win solution for all stakeholders. Within each of the cities, the citizens and the community benefit from the availability of better, more innovative, and cheaper applications and services. The cities benefit from the reduced development cost and faster development times

enabled by a standard platform, together with the ability to choose vendors freely and avoid vendor lock-in.

They will be able to identify new sources of revenue by unlocking data assets and will unleash innovation from entrepreneurs and the community without any cost to themselves. The industry will benefit enormously through the improved ability to find skills and rapidly ramp up projects.

They will also see reduced development expense enabled by a standardized and open-source platform and be able to focus on innovation and differentiated value rather than design basic platform software. A simplified picture of the IUDX architecture and its application to an emergency management use case, is shown below.

Figure 54: India Urban Data Exchange Architecture (IUDX) use case applied to emergency management.



7.7 Smart Destination Platform

Context and framework within which the initiative is developed

The health crisis caused by the COVID-19 pandemic completely disrupted the existing social and economic dynamics of the world. In addition to the devastating consequences on the physical integrity of part of the population, the pandemic also compromised the global economy, directly affecting unemployment levels and the restructuring or extinction of a considerable part of the productive framework.

In this context, the member states of the European Union quickly adopted a set of coordinated emergency measures to protect the citizens' health and palliate the economic collapse. Under these measures, a drastic economic and social effect was noticed in the European Union countries as a whole, directly influencing the business activities of cities.

The unprecedented context in which the COVID-19 crisis immersed us, motivated the need to quickly react by adopting urgent and categorical measures to, not only cushion the effects of the pandemic and impulse an early economic recovery, but also to lay the foundations for development in the coming years.

Aware of the singular moment in which the world found itself, the European Council agreed to the launch of the Next Generation EU as the innovative approach required for the transformation of its member states. The central axis of this instrument was the Resilience and Recovery Mechanism, through which European countries would cope with the economic and social effects and, at the same time, begin a transition towards ecological and digital models aiming at principles such as sustainability and resilience.

Based on the above, the Spanish Government elaborated the Recovery, Transformation and Resilience Plan (PRTR) "*España Puede*", which includes ten tractor policies or levers that will have a direct impact over those productive sectors with a greater capacity for transforming the economic and social structures.

Clearly, one of these ten policies of great scope orbits around the competitiveness of the industrial and SME sectors, putting their modernization and digitalization in the forefront, along with the recovery of the tourism sector and the promotion and encouragement of Spain as an entrepreneurial country.

To achieve these objectives, the Spanish Secretary of State for Tourism (SETUR), through SEGITTUR,[62] launched the Smart Destination Project, which boosts tourism development in tourism destinations through a model based on five concepts: governance, innovation, technology, sustainability and accessibility.

Smart Destinations are created with their own model, supported by a collection of public standards in alignment with the standards for Smart Cities, under the Smart Destinations Subcommittee 5, within the Technical Standardization Committee AEN/CTN 178 Smart Cities.

In addition to creating the conceptual framework for Smart Destinations, in 2019, SETUR launched the pioneering initiative, the Smart Destinations Network,[63], which features tourist destinations as the protagonists, and provides a meeting point and support for these destinations as they transform to follow a model for smart management and more sustainable tourism development.

During the COVID-19 crisis, the Smart Destinations Network has shown itself to be an effective instrument for implementing measures and actions in response to new challenges, adapting its model to the challenges that tourism management must overcome, creating spaces for collaboration and developing knowledge, resources and services to support the recovery of tourist destinations. The Spanish Smart Destinations model, a global trailblazer, has been recognized by UNWTO, the World Travel & Tourism Council (WTTC), OECD and the Inter-American Development Bank.

The integration of smart tourism into the existing framework has the potential to address conflicts between residents and tourists, improve the quality of services offered to tourists, and provide the public with better information. The implementation of enabling technologies can also help to transform the tourism industry and make it more competitive by providing tailored services that meet the expectations of modern travelers. This can lead to an overall improvement in the tourist experience and help to ensure the long-term sustainability of the industry.

Smart tourism and sustainable cities are two important concepts that are closely related to each other. Smart tourism refers to the use of advanced technologies and data analysis to enhance the tourism experience and create more efficient and sustainable tourism systems. On the other hand, sustainable cities are those that have been designed and developed in a way that minimizes their environmental impact and promotes social and economic well-being.

In the context of smart tourism and sustainable cities, there are several ways in which these concepts can be integrated. One example is the use of smart technologies to manage tourist flows and reduce overcrowding in popular tourist destinations. This can help to minimize the environmental impact of tourism and ensure that local residents can continue to enjoy their city without being overwhelmed by tourists.

In order to make smart tourism and sustainable cities a reality, it is important to involve all stakeholders in the planning and development process, including local residents, businesses, and government agencies. This requires a collaborative approach and a commitment to long-term sustainability goals.

Overall, the integration of smart tourism and sustainable cities has the potential to create more efficient and enjoyable tourism experiences, while also promoting environmental, social, and economic sustainability

Spain is a world leader when it comes to tourism. This economic activity amounted, in 2019, to nearly 12 per cent of the GDP and 14 per cent of employment. That same year, the country almost topped the world expenditure by tourists ranking with nearly EUR 90 million, and the world tourist arrivals ranking with more than 80 million international tourists.

Nevertheless, the Spanish tourism sector was not spared the consequences arising from the health crisis, currently finding itself at a delicate moment in which the implementation of a modern and competitive strategy that faces these impacts and paves the way for the pending major transformations is vital.

Rising to such a challenge, the PRTR contains a specific component aimed towards the modernization of the tourism sector by encompassing different strategic axes such as destination and tourist products sustainability, energy efficiency and circular economy bolstering, digital transformation and competitiveness renewal. This component had an estimated investment of nearly EUR 4 000 million, corresponding to 10 per cent of the digitalization axis, which is key when attracting tourists who are progressively more hyperconnected. Moreover, only through the deployment of actions of this nature will the tourism sector be able to take advantage of its potential as a receptor of the added value that technologies such as Artificial Intelligence could represent for this activity.

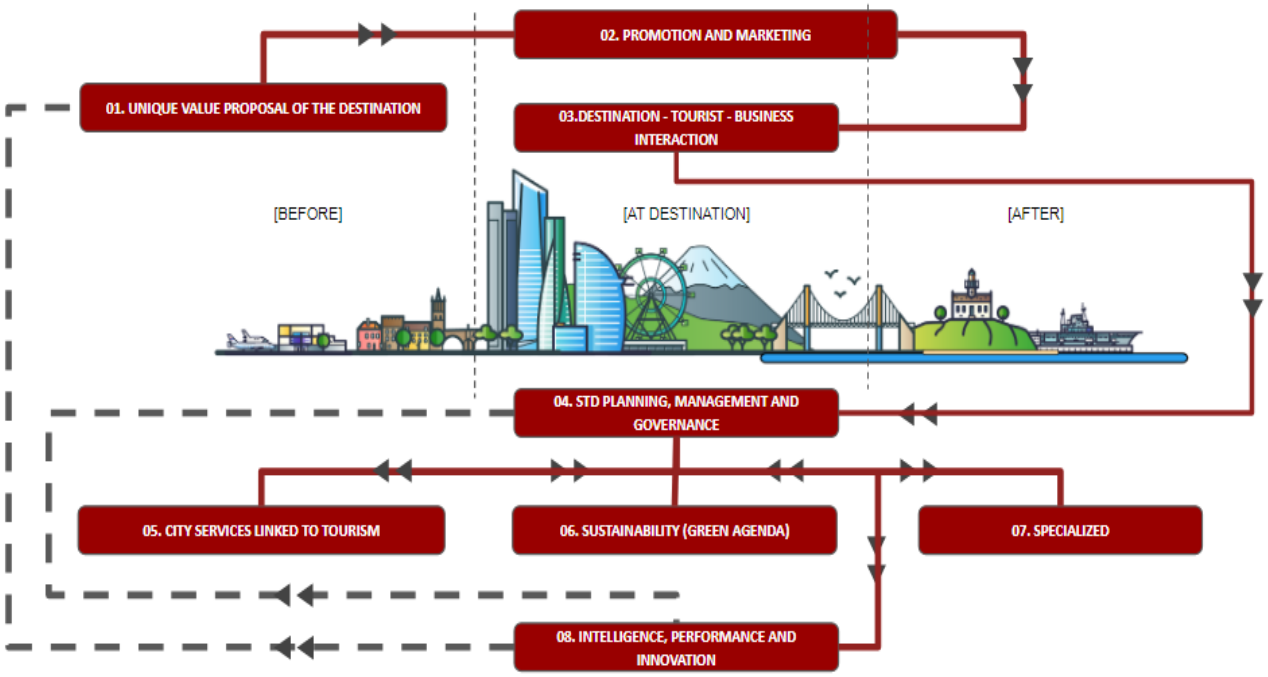
Consequently, the PRTR anticipated the development of new digital tools within a continuous innovation process to ensure the sustainable development of destinations, addressing aspects such as accessibility, tourist interaction and integration with the environment, and improvement of the experience and the quality of life of residents.

Smart Destination Platform: Definition, objectives and scope

A concrete example of the harnessing of new technologies is the implementation of a Smart Destination Platform that improves the interoperability of the public and private service offer. Simultaneously, this gives all agents the opportunity to relate digitally with the tourists. This is a Platform that provides added value services to the members of the Smart Destinations Network and a common national technological infrastructure to boost the digital transformation of Spanish tourism destinations.

Involved in its creation are the Spanish Secretary of State for Tourism through the State Company for the Management of Tourism Innovation and Technologies (SEGITTUR), who currently defines the Smart Destination Platform as a shared services platform that incorporates a collection of digital solutions that solve key public issues and market failures, at digital and physical levels, throughout the tourist travel cycle. This tool will be capable of a country scale management with hundreds of destinations and thousands of SMEs connected and monitored, it will also contribute to the acceleration of the digitalization of key processes, the improvement of the tourist experience, the carbon footprint reduction, the companies' business figure improvement and the generation of prosperity for citizens, all aimed at achieving a competitive model based on data and algorithms.

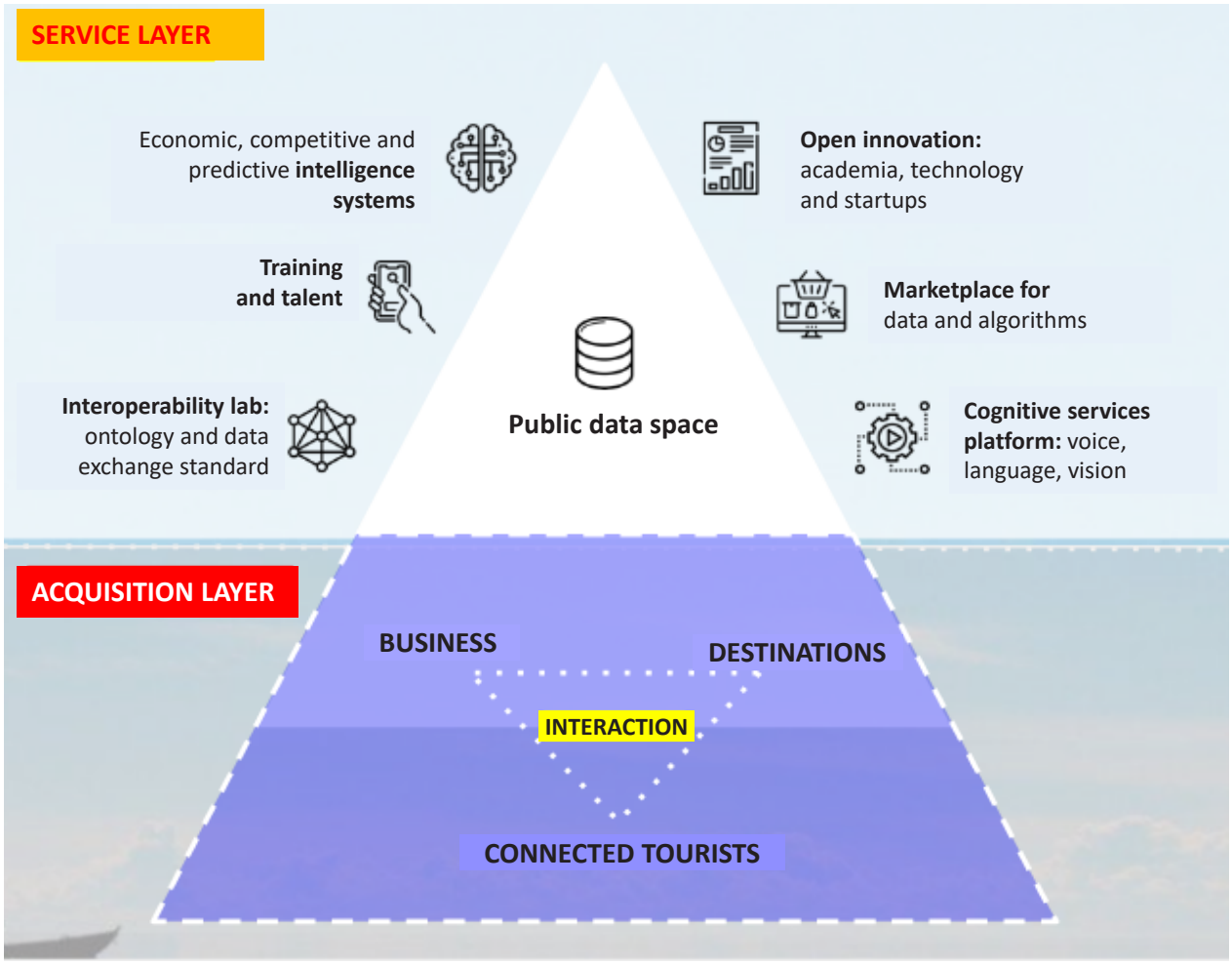
Figure 55: Smart Destination Platform solutions throughout the tourist travel cycle



This project aims to place Spain at the forefront of tourism countries by using digitalization to improve the tourism experience and offer integrated services of value at the destination. Therefore, the objective of the Platform will be to integrate, relate and combine public and private data to generate more competitive intelligence in the ecosystems of Spanish destinations, activating continuous innovation, and interconnecting and addressing the needs of all stakeholders in the tourism value chain: tourists, destinations and companies.

Furthermore, the Smart Destination Platform is an initiative in favour of technological sovereignty and the competitiveness of Spanish tourism based on profitability, sector cohesion and the generation of knowledge to address the challenge of the digital transformation of Spanish tourism in its social, economic and environmental angles.

Figure 56: Tourism value chain interaction through the Platform common services



For their part, tourists will be able to interact digitally with the destination and its private offer, maintaining loyalty before, during and after the trip through different channels such as social networks, websites or apps. Moreover, the Platform will help to simplify the planning processes before the trip and improve the inspiration phase, enhance the personalization of the tourist experience and increase the propensity to consumption and their degree of satisfaction, and maintain a post-trip relationship with the destination brand where they are encouraged to make new visits through personalized recommendations in line with their motivations.

From the destination's point of view, the Platform responds to the main challenges they face in their constant transformation process. Encompassing promotion in markets, tourist information provision, interaction with tourists during their stay, their impact over public services like mobility, waste and security, the analysis of the physical and digital behavior of tourists by seasons, market segments or by applying predictive intelligence.

For companies, the Platform accelerates their business digitalization process in the promotional sense and in the interaction with tourists and strengthens the technical preparation of the teams.

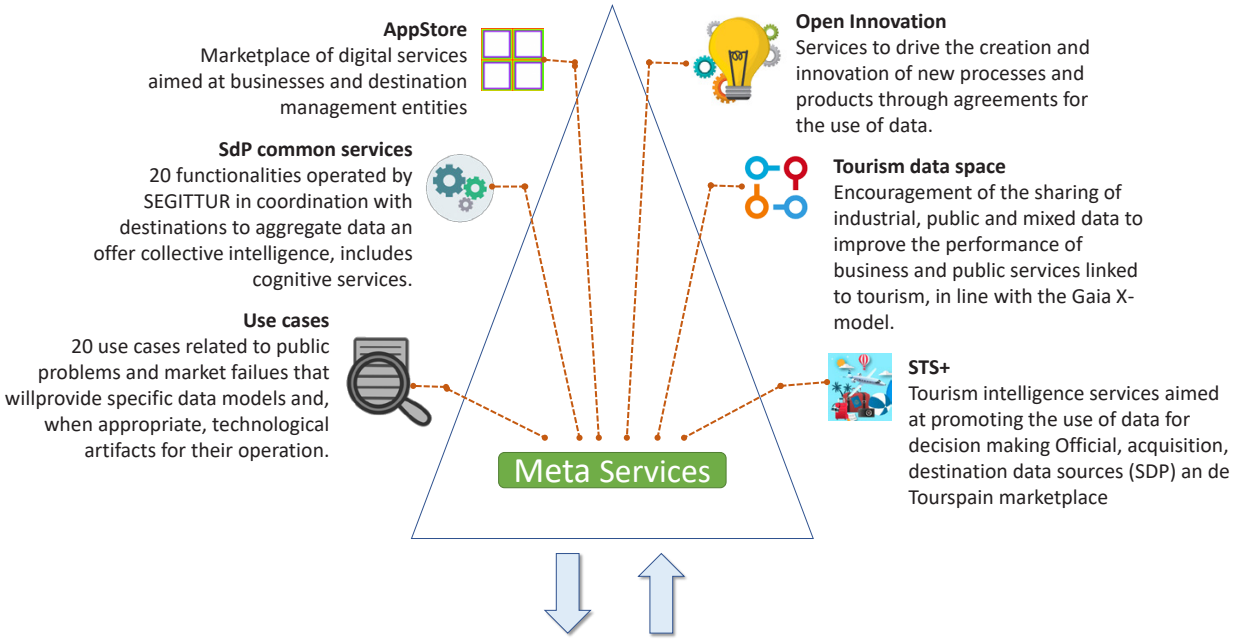
It also provides tools to generate better value propositions and their diffusion through the best channels operated by the destination for its promotion. In addition, business intelligence is also provided, making it possible to compare a business situation with similar situations, either at the same destination or at competing ones.

In this way, the digitalization of tourism services, data and artificial intelligence are positioned as levers to accelerate the shaping of the Spanish tourism model and, for this purpose, EUR 130 million will be allocated from the said PRTR.

Technical conception

The Smart Destination Platform must be understood as a meta-platform that deploys proprietary and third-party applications, integrates operations from the latter and interoperates bidirectionally with data from other third-party platforms, data centres and applications. Therefore, its structure will have a modular design, in order to add components progressively and allow the creation of new shared solutions applicable to destinations with similar contexts and needs. In this way, reusability of services will significantly optimize costs and improve its deployment speed.

Figure 57: Meta-platform services



This meta-platform will establish an operational bifurcation in at least two directions: the marketing and sales vector and the destination interaction vector. The different nature of the processes of each of these justifies this division, taking into account the existing market developments and their individual specializations. Because of this, the meta-platform should integrate both realities to make the objectives of the initiative feasible.

The destination interaction vector will be the dominant one, considering the functionalities required for the main driving element, the destination, and should integrate the marketing and sales vector as an inherent part of the initiative.

Once all the planned processes of the Smart Destination Platform and the deployment of these capabilities in the city and tourist offer have been activated, the largest exercise of data acquisition on the tourism system will begin. These data will be reliable, stable and updated from the digital and physical dimensions covering all stages of the travel cycle, allowing the analysis and creation of the necessary time series to activate AI applications.

In this sense, data governance becomes a key element for the success of the initiative. Therefore, it will be necessary to define a data governance model capable of managing the data that will be fed into it from the different existing systems and from the applications that are part of it, guaranteeing its correct use, storage and exploitation.

The development of the applications from where these data come is possible thanks to the combination of some enabling technologies like artificial intelligence, machine learning, natural language processing, Blockchain, Semantics, Open Data, Big Data, Internet of Things, Social Network Analytics, and Cloud Services.

The latter of these acquires a special importance, since it not only allows cities to face new market challenges in a more flexible and agile way, but also eliminates the geographical barriers for the deployment of solutions, so maximizing implementation speed. Moreover, the Platform is conceptualized as a service mode platform. Therefore, it will be deployed in a cloud that guarantees high availability of the service and complies with the national security scheme for clouds. This service deployment strategy will allow cities to join the initiative in a simple and controlled way that facilitates the adoption of the solution by a large number of them.

The characterization of this cloud should support a global platform to be deployed in a SaaS mode, allowing the establishment of the foundation upon which all cities reside; and, on the PaaS Platform, the hosting of the different applications of this initiative as SaaS solutions that cities could consume directly. In this sense, all applications will be deployed and executed on the Platform's cloud architecture following a DevOps methodology. This model would allow an efficient execution of the services under the same data container, always instantiated to comply with the privacy of each destination, taking advantage of a core technology for all of them.

At the same technological level, the Platform should also be designed under a sensor architecture that allows its extension to address IoT use cases, supporting hybrid Cloud-Edge models. This hybrid Cloud-Edge strategy to process data close to where it is generated will allow: "real-time" IT/OT convergence, device orchestration and monitoring, hardware manufacturer independence, proactive control of the installed base, end-to-end security, and so on.

In order to provide the initiative with real city data, it is proposed that consideration be given to the deployment of a sensor base to establish the groundwork for the transformation of the city.

The data sets must be the raw material for the creation of new public policies and actions and of commercial actions linked to reliable city information.

Thus, it is essential to generate a destination data architecture supporting the acquisition, processing and analysis at all levels: critical physical spaces of tourist interaction, public support services, digital channels of interaction at destination, tourism companies and resources.

Finally, in order to meet the needs of the initiative, interoperability is a key element for its success. Without the interoperability of the systems, it would be impossible to build an initiative of this nature. This requires that the solutions that make it up offer open interfaces that guarantee interoperability, modularity, scalability and reuse of applications.

Governance and co-creation process

The starting point for the construction of the Smart Destination Platform was a dialogue process, since it was intended to be a co-creation exercise that defined and established the scope of this project. This dialogue process consisted of two presentation rounds including representatives from networks of cities and destinations, business associations, and other stakeholders. The first of the rounds set, collaboratively, the objectives, description, scope and specifications of the Platform. The last round aimed at delving into its focuses, structure and extents, taking into account new points of views from said representatives, and building a list of critical topics to keep track of.

This co-creation process allows a common vision of the profile and scope of the Smart Destination Platform, from which a promoting entity with public and private participation was established with a clear role in the design and development of the platform. It is a body for coordination and cooperation with the tourism and technology business sectors and the city networks that give continuity to the participative process that has defined the approach and scope of the Platform.

Among its functions is to ensure that the design and implementation of the Smart Destination Platform is aligned with the needs of destinations and their socio-economic ecosystems, to know and report on the various actions being developed: state of the art studies, pilots and use cases that will activate some of its basic and specialized capabilities, which will facilitate interoperability with other public and private platforms, thus enhancing the operational capacity of the sector and generating new governance and data usage scenarios.

Through the joint work under this promoting entity, a series of documents have been developed to determine the scope of the platform. These documents, fruit of the co-creation process, are:

- Functionality Model of the Smart Destination Platform
- Model of Layers of the Smart Destination Platform
- Smart Destination Platform holistic vision of platforms and solutions
- Tourism Interoperability Laboratory Bases

As a whole, these documents set the scope of the platform under seven groups:

1. Smart City and Destination capabilities: technologies that put at the service of tourist destinations the capabilities of data intelligence to address the critical dimensions of local tourism management (flows, concentration, interaction and performance), opening up new possibilities for City Councils as generators and managers of data.
2. IoT layer: deployment of sensors in the territory at points of tourist affluence, plus the integration of other devices already installed.
3. Solutions for decarbonization: identification of critical aspects, potentials and opportunities to reduce and offset the carbon footprint of public services offered and the tourism sector.
4. Solutions for the improvement of marketing, promotion and sales of the value propositions of destinations and the tourism products and services of the implicated tourism businesses.
5. Management and participation solutions that serve implementation, knowledge, coordination and management processes.
6. Specific applications for programme beneficiaries with access to resources and services.
7. Solutions for the massive and effective training of the different users of the system.

The Smart Destination Platform establishes itself as an integral solution for smart and sustainable cities, since it places tourists along with citizens in the centre of the four-area defined strategy. This initiative will make use of the city data as its raw material and of enabling technologies as its backbone, employing them to the benefit of all stakeholders, with the availability of improved and innovative applications and services.

For their part, cities will benefit from the cost efficiencies derived from the disposal of a standard platform with a modular design, thus allowing the addition of new components to better adjust its scope to each city's reality.

On the other hand, the tourism offer will be able to identify new sources of revenue thanks to the data assets that will be acquired, analysed, communicated, and shared. Moreover, the industry will benefit tremendously from the massive formative actions to generate talent and provide skills supporting the digital transformation.

Finally, as a centralized instrument, it will allow synergies to take place instead of the siloed model that usually prevails, thus helping to avoid isolated actions that generate duplicates and inefficiencies. In this way, the platform will contribute to the creation of a common technological ecosystem capable of an automated and sustainable resource management, the supply of interoperable capacities much needed for resource and data sharing, and the improvement of processes related to the acquisition, analysis, communication and sharing of data.

8 A Path to City Transformation

The backgrounds, capabilities, strengths, and strategic objectives of cities are very different, and it is not possible to develop a single global solution for their transformation, intelligence, and sustainability needs. Nevertheless, new technologies and new ways of working create opportunities to improve cities, and these opportunities should be used by all cities, regardless of their size, capabilities, resources, or stage of development.

This people-centred digital transformation of cities must be based on strong governance together with leadership at the highest levels of decision-making, the alignment of stakeholders' expectations and the use of the experience accumulated by other cities. The use of standard, ready-to-use solutions, along with regulatory support of national standards and other ITU and UN resources publications and reports, represent a valuable source of information that allow to avoid investments in expensive solution development from scratch and establish a path of growth capable of adapting to an uncertain demand for solutions for citizens.

- How to develop a smart city strategy and who to involve?
- What role can cities play in adopting smart city solutions from the point of view of their own digital transformation?
- What projects are relevant and how to avoid silos?
- How to measure the evolution of the city through KPIs and other tools?
- How to involve the different stakeholders?

The U4SSC Thematic Group of City Platforms[64] has published different documents related to the transformation of a city into sustainable and intelligent, and that may be of interest to managers, citizens and actors interested in this market.

The first paper "*IT Solutions for integrated cities management & Use Cases*" describes the experiences of different cities in their transformation process into SSC and provides some interesting insights into where the "smart city platform market" currently stands, some of the barriers faced by cities that lead to non-implementation (or limited implementation) of platforms, how these barriers can be overcome or mitigated, and what are some of the key success criteria and factors for successful implementation and utilization.

The second document *"Smart Public Health Emergency Management"* explores the context of public health and the importance of active surveillance mechanisms in the urban ecosystem to enable emerging communications for public health disasters and the incorporation of IoT, Artificial Intelligence and data-driven frameworks to provide timely responses to epidemics and pandemics,

while implementing generic public health operational processes derived from the methodologies adopted for past crises. Moreover, this document concludes with a smart public health framework, which utilises these tools, and defines a pandemic life cycle and specifies when mass surveillance tools are applied.

The third document, *"Smart City Platforms-Transitioning to a new architecture",* provides guidance to government stakeholders on setting up/procuring smart city platforms. This document illustrates the current state of the art of interoperable smart city platforms and provides recommendations for technical specifications. It shows how to build capacity in the use of the standards, mechanisms, services, guidelines and tools that enable the interoperability of data platforms for cities and communities, to speed up the delivery of services leading to innovation and positive local impact.

The fourth document, *"Tourism, Health and Resilience Management from the perspective of a Smart City Platform",* shows an example of how the experience of sustainable and smart cities can be transferred to other sectors of the economy, in this case to the tourism sector under the paradigm of "Smart Tourist Destinations" (STD).

A Smart Tourist Destination makes intensive use of the technological infrastructure provided by the Smart City to improve the tourism experience of the visitors, personalize it and make them aware of the tourism products and services available in the destination. STD is considered an innovative space based on the territory and a cutting-edge technological infrastructure, committed to sustainability, with an information system capable of analysing and understanding events in real-time, thus facilitating the interaction between the visitor and the environment.

The strength of tourism as a global phenomenon is currently reinforced by the growth of high-speed and low-cost transportation that provides more visitors with access to city breaks. Furthermore, an increase in the popularity of cities as tourism destinations is also in place due to a new demand seeking experiences associated with the diverse ways of life provided by urban spaces.

This spotlight on cities justify the integration of the tourism management perspective inside the smart and sustainable city framework[65], which must consider the massive volume of tourists who make use of the urban public spaces and services becoming temporary residents. The anticipation of this phenomenon from a strategic standpoint will mean the difference between the inclusion of tourism in the wider city agenda as a means to make it a true contributor to its inclusive and sustainable development and falling victim to important challenges regarding the use of natural resources, environmental challenges, socio-cultural impacts, infrastructure pressures and the relationship with locals.

The creation of smart and sustainable cities holds enormous potential to generate a positive impact on citizens' lives and tourists' experiences by making cities more livable, attractive to invest in and visitable by reinforcing its authenticity values.

Finally, the fifth document (present document) "*Reference framework for an integrated management of a smart sustainable city*" offers a more operational overview of the processes underlying the

transformation of a smart and sustainable city. Different chapters deal with aspects not included in previous documents such as connectivity, or the ICT technological ecosystem.

Because cities must address very important challenges that affect multiple areas of the city itself, it is necessary to generate a roadmap for the transformation and integrated management. It seems reasonable that this integrated city management pivots on an urban data platform that centralizes the data collected by IoT devices, as well as municipal information systems, allowing analysis capabilities on them to turn this platform into an open hub in the transformation of municipal services and for the entrepreneurial and research sector of the local environment.

From the experience accumulated by the authors, defining a hypothetical path towards the transformation of a city into smart and sustainable is a process that it should be based on three pillars:

- First and foremost, the leadership of municipal managers to provide not only material support, but also an organizational structure with executive capabilities to carry out this transformation.
- Secondly, a City Strategic Formulation, including action lines and management support.
- And at last, but not least, a City ICT Formulation, that technologically supports this transformation, plan the necessary investments and resources to guarantee the efficiency, re-use and sustainability of the projects.

Figure 58: City SSC transformation keys

8.1 Leadership

The digital transformation into a smart and sustainable city represents a challenge not only technological but also organizational and cultural.

In an environment of increasingly limited resources, organizations tend to promote minimal change in the face of the uncertainty that this entails. This occurs especially when they are of a technological nature, affect different departments in a transversal way and require the development of new skills in the people involved.

The evolution of more vertical traditional models in project management with respect to more horizontal and collaborative models, can generate conflicts in static organizations. Municipal departments historically manage areas of vertical activity such as waste collection, water and lighting, watertight in compartments that operate autonomously. In many cases, service managers consider that this kind of transformation does not give them a differential value or produce external interference, or permit foreign control of their activity or, in the medium term, unpredictable organization changes.

Ensuring the success of this SSC transformation requires a commitment at the highest municipal levels, politically, economically and organizationally. The transformation into an SSC is a long process and is not without difficulties where the continuous thrust of senior management is a key. Undoubtedly, any change will generate extra work and effort, and if the management is not always motivated and pushes things down to the lower levels, there is a risk that the day-to-day complacency will make the attempt fail.

Creating a specific organization for this process (Smart City office) can be a key factor for success in this transformation. Having a global vision of the entire process with specific responsibilities allows planning in the short, medium, and long term, so generating trust and confidence, and improving communication. This department is configured as a transversal element and support to the rest of the municipal areas, especially to the internal ICT areas.

8.2 City Strategic Formulation

The strategic formulation must be the first point of action to consider in the transformation of a city into a smart and sustainable city. In Figure 59, the authors have arbitrarily defined three axes of action that begin with a diagnosis of the current situation of the city (situational analysis & best practices), followed by the definition of the vision and objectives (aspirational analysis & priority lines of action) and finally, a governance structure (organization, resources, city services evaluation & communication) that guarantees the success of the city's transformation.

This strategic formulation must be materialized in a document shared by all stakeholders, which can be used as a guide to this path of transformation.

8.2.1 Diagnostic and actual context

This first block will develop a situational analysis, with elements intrinsic to the city itself such as population, economy, geography and budget, as well as the study of best practices worldwide and their possible application in the city.

The current situation, and the impact of the COVID-19 pandemic, has been a great challenge for all cities, especially in developing countries. The technological needs, the standardisation, and the use of the data are the challenges they are facing. Complex challenges facing cities require managing information from multiple areas of the city, as well as from other institutions and private entities. As a result of the analysis of this point, the city will have a diagnosis of its strengths and weaknesses, as well as a description of the hypothetical threats and opportunities on this path to transformation.

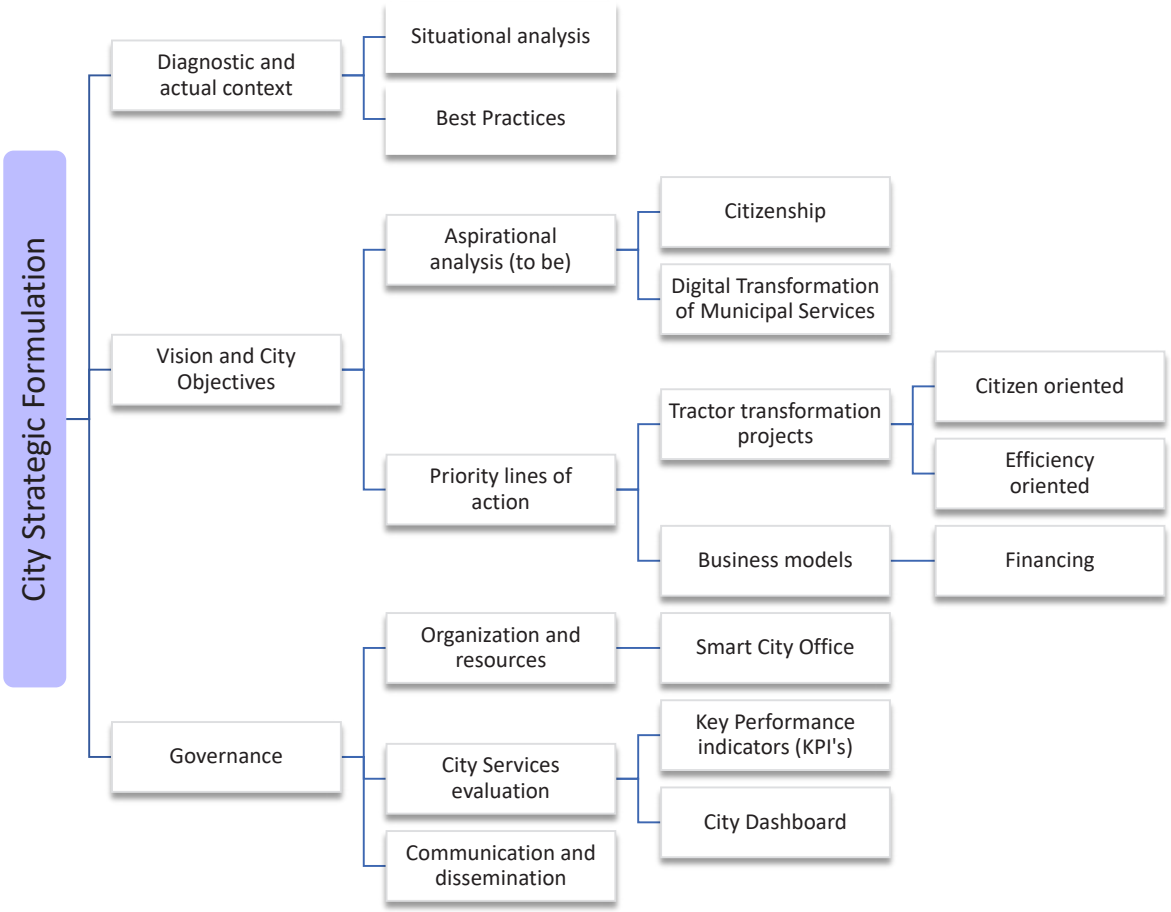
As for best practices, we can turn to the compendium[66] released by Working Group I, of the survey results provided by the representatives of the cities to lay the groundwork for the research and drafting of the report on Digital Solutions for Integrated City Management and use cases. Illustrated by success stories, this document presents the experience of cities, communities and municipalities participating in the U4SSC initiative in developing their smart city strategies, the governance of smart projects, and the principal role of a smart city platform (or set of key components that constitute it) in contributing to improving the lives of their citizens.

The cities also described the technical-administrative and project management organizations that support their city's strategy, as well as their competencies responsibilities. They defined their commitment to standards (in the procedural and technological aspects) and the use of ICTs in the management of U4SSC key performance indicators (KPIs).

Finally, the smart sustainable cities described their experiences in the relationship with their citizens, the innovation ecosystem, and the networks they worked with for the design, sharing and replication of smart and sustainable city solutions.

The selection of the use-cases has been conducted to highlight the experiences and results from various cities across the globe, with the expectation that this will provide considerable value for other cities.

Figure 59: City Strategic Formulation



8.2.2 Vision and City Objectives

In this second axis, based on its capabilities and the result of its initial diagnosis, the community would define what the objective scenario would be in the short, medium, and long term, considering, in turn, how to offer more and better services to citizens, and on the other hand, how to improve municipal internal efficiency.

The adoption of a human-centred design approach is a key point. This focuses on exploiting the human experience from the diverse perspectives of the people who live, work, learn and play in cities every day to design solutions adapted to their needs.

However, it is not possible to satisfy the services demanded by citizens with a limited budget. To this end, the strategic formulation must prioritize certain lines of action and focus resources in "tractor" transformation projects that have a huge impact for citizens and/or the city itself.

A recommendation of the authors is that the lines of action be made to coincide with the "*Smart areas*" defined in recommendation UNE 178201-2 *"Systems for managing Smart Cities and Balanced scorecard indicators"*[67], or with the dimensions defined by U4SSC (economy, environment, society) in USSC Key performance indicators documents.[68] This will make it easier for the governance area to assess and follow the results of the underlying projects using standardized indicators.

The "tractor" projects should be selected according to the city strategy, the impact on citizens or efficiency, implementation time, technological limitations and finally on sustainable business models, and having adequate financial resources not only for their execution (CAPEX) but also for the sustainability in the future (OPEX).

8.2.3 Governance

This is the central axis to ensure the success of the transformation of the city and support the global coordination with all the actors involved. In this axis, three areas of action have been defined: the first related to the organization and resources; the second related to the evaluation and monitoring of the progress of the transformation of municipal services; and finally, the management of internal and external communication.

As noted in the section 8.1, smart city projects are generally multidisciplinary and involve different areas of the organization, as well as collaboration with external stakeholders. This task of coordination between areas is one of the main risks identified.

Organizations and resources

The creation of a smart city office, made up of a multidisciplinary team, can be a guarantee to align the city's vision and strategy, along with its policies for the digital transformation of municipal services, the unified management of information and normalized relationship with external agents.

The improvement of the municipal organization, at the organic, functional and resource levels, as well as the means of management and preparation of services to the citizen implies not only the electronic collection of data and information and their proper treatment but also their practical use as an objective parameter for decision-making.

City services evaluation

Unified governance becomes an opportunity to monitor and evaluate city service departments and subcontracted companies. City dashboards and the introduction of "smart clauses" in the technical specification of public procurements help to standardize the integration of data and reports provided by internal departments and external stakeholders using open standards.

This is the basis for a correct assessment of the degree of progress in the city's initiatives. The development of international standards in the field of smart cities has made it possible to have a common methodology of city indicators (in the form of KPIs) to allow cities to monitor the fulfilment of their objectives, including SDG, and to be compared with other cities (if required). The definition of these indicators allows for the identification of best practices and helps to define objectives for action plans or projects.

The use of dashboards and the inclusion of standardized indicators is very useful to facilitate the evaluation and monitoring of how initiatives and policies are managed in the territory. The dashboards must have an interface adapted to the municipal organization, integrating all kinds of resources allowing the data to be consulted in a georeferenced way using the municipal geographic system from the dashboard itself and integrated with the open data portal.

This implicates the possibility of offering citizens access to certain municipal information, "*open data*" becoming the citizen an essential protagonist and receiver of all the actions developed in their natural habitat and a fundamental pillar of the digital transformation of this environment.

Communication and dissemination

Fluid and effective communication with citizens is essential to transmit the actions carried out in a sustainable and smart city. As an example, a portal connected to the Internet that functions as a bulletin board with interactive information where citizens and City Council workers can consult data in real time on the areas of greatest interest such as traffic, capacity of public car parks, pollution levels, temperature, the evolution of employment, the municipal agenda and social networks.

Notice that this framework would not be possible if the municipal information systems were not connected to the city platform.

8.3 City ICT Strategic Formulation

The ICT strategy must be a consequence of the city strategy described in the previous section since there are different institutional, economic, human, and technological factors that are decisive for its definition and development.

Cities have long had systems for municipal management designed ad hoc, and as self-contained applications. These systems have a high maintenance cost, are not flexible and their adaptation to the new services demanded by the citizens represents an economic, cultural, and organizational challenge. This is undoubtedly one of the most important points in the transformation of the ITC ecosystem, given that it must evolve towards a flexible and scalable architecture that can adapt to new needs with minimal costs. Therefore, the ITC ecosystem must evolve towards a flexible and scalable architecture that can adapt to new needs with minimum costs.

Due to the heterogeneity of the systems and the high investments required, it is necessary to design, as in the strategic formulation of the city, a strategic ICT formulation that establishes the path of this transformation. In Figure 60, a hypothetical roadmap has been drawn, which, at a high level, describes the steps necessary for this.

An ICT roadmap must be developed simultaneously and coordinated with the strategic formulation, due to the strong dependence between the two. Technological leadership and ICT governance must be closely linked to the area of governance, given that without adequate ICT planning the priority lines of action could not be developed, and conversely, without defined lines of action, investments in ICT could not be efficient or adequate for the needs of the city.

Finally, it is important to highlight the need to complement the ICT strategy with the management of the necessary cultural change in the municipal organization. Legacy systems have been operating with good performance for a long time, and the organization's logical resistance to change, as well as its adaptation to new ways of working, represents a challenge that must be evaluated and managed properly.

8.3.1 Context and Current Diagnosis

This axis is the first element of analysis. The city must evaluate the state of its different information systems, databases, platform of administrative procedures and if it has geographic information systems that allow this component to be incorporated into city information.

A situation analysis of the existing systems, their degree of obsolescence, operating costs, administration and maintenance, and so on, will be carried out. As main points, the ability of applications to share information in an automated way with external systems through, for example, Service Bus, ETL, will be analysed.

Next, the best practices will be studied, as well as the different options for the commissioning of a city platform that allows solving new needs such as interacting with IoT devices, offering Big Data storage capabilities, analysis, and integration with legacy systems, among other things.

The experiences derived from the smart cities covered in the first report[69] provide some interesting insights into where the "Smart City platform market" is at present, along with some of the barriers that cities face which led to non-deployment (or limited deployment) and how they can be overcome or mitigated, and what some of the key success criteria and factors for successful implementation and utilization are.

This analysis must be aligned with the objectives and vision of the city, as well as with the short- and medium-term needs of the information systems, necessary to support the projects derived from the priority lines of action.

8.3.2 Technological leadership & ICT governance

As in the strategic formulation of the city, technological leadership and ICT governance play a primary role. In many cities, much of the administrative systems are legacy and their replacement in the short term is generally economically unapproachable.

Technological leadership and ICT governance are complementary elements to strategic governance since both have a high technical component and their management should be in the hands of professionals with a very high level of specialization. In many cases, this area of management should fall to technology departments or external companies.

With the information contained in Chapter 3 "City & ICT Governance", the city would be able to understand and prioritize projects and investments, in addition to establishing a path for the migration of legacy systems, taking advantage of the synergies offered by city platforms.

In Figure 60 a reference to the Smart City Offices has been included, which although they would be an element of the strategic management of the city, should act as an element of union with the internal ICT areas to:

- Cooperate or coordinate in ICT projects related to the territory and georeferencing.
- Develop methodologies and work regulations related to the introduction of ICT in public services.
- Direct and coordinate the integration and functional compatibility of projects with computer systems and Smart City technologies.

Finally, ICT governance needs to consider the IT processes and procedures that must necessarily be redefined and adapted to new needs, especially those related to administrative processes (e.g., electronic office, payments, electronic registration).

8.3.3 Reference ICT technological architecture

Once the environment and best practices have been identified, it is time to draw the long-term reference technological architecture model, connectivity, the IT ecosystem, and finally the business components and applications.

The connectivity of a smart community has been discussed in Chapter 5, where different solutions that may be of interest to the city in the field of personal communications, infrastructures and IoT devices are discussed. At this point, availability, costs, coverage, and the regulatory environment play a major role.

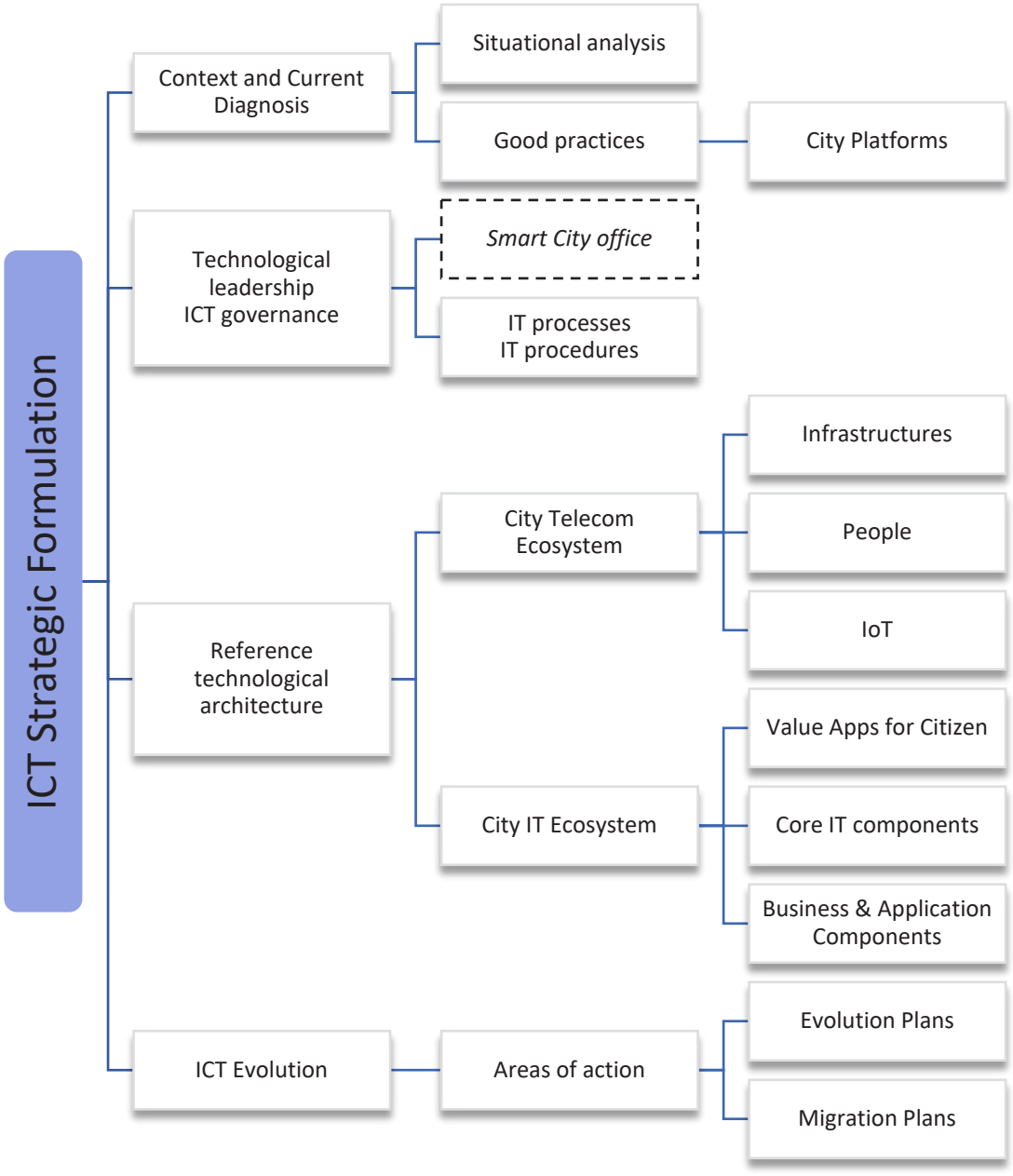
Having a flexible, efficient and ubiquitous network is a fundamental part of the city's strategy, since the access of citizens, companies and other actors must be guaranteed with adequate security and availability measures.

The design and operation of a private, convergent communications network (municipal corporate network) together with virtual private network services offered by telecommunications operators, offers, in the medium-term, lower operating, administration and maintenance costs in addition to the essential security needs in an SSC environment.

City ICT systems are the key elements that allow municipalities to support relationships with citizens and administrative systems. At this point, there are different transformation approaches. A pragmatic approach of many cities to this transformation has been to make legacy systems coexist with new cloud-based solutions (private, on-site or public) building an architecture based on microservices and containers. Chapter 6 describes the city IT ecosystem in detail.

The city platform, the e-government platform, the municipal database, and the geographic information system would make up this basic core (city IT core) on which administrative information services, citizen services, as well as interconnection services with other external stakeholders would be developed.

Figure 60: ICT Strategic Formulation



The connectivity of a smart community has been discussed in Chapter 5, where different solutions that may be of interest to the city in the field of personal communications, infrastructures and IoT devices are discussed. At this point, availability, costs, coverage and the regulatory environment play a major role.

The design and operation of a private, convergent communications network (municipal corporate network) together with virtual private network services offered by telecommunications operators, offers, in the medium-term, lower operating, administration and maintenance costs in addition to the essential security needs in an SSC environment.

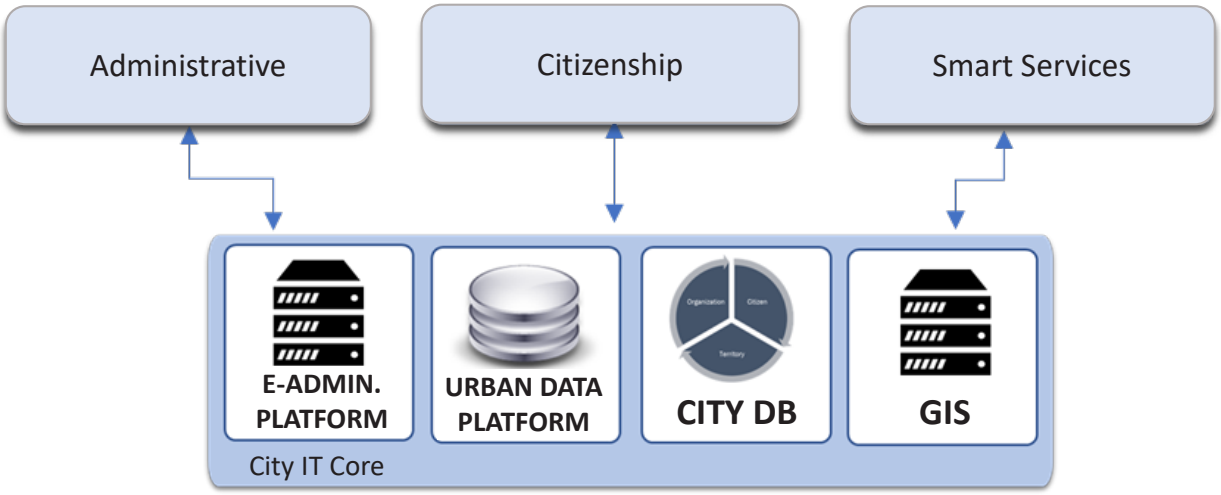
City systems are the key elements that allow municipalities to support relationships with citizens and administrative systems. At this point, there are different transformation approaches. A pragmatic approach of many cities to this transformation has been to make legacy systems coexist with new cloud-based solutions (private, on-site or public) building an architecture based on microservices and containers. Chapter 6 describes the city IT ecosystem in detail.

The city platform, the e-government platform, the municipal database and the geographic information system would make up this basic core (city IT core) on which administrative information services, citizen services, as well as interconnection services with other external stakeholders would be developed.

Once the core IT ecosystem has been deployed, on this common infrastructure, the city could be able to:

- Develop new applications of value for citizens and city officials.
- Develop smart applications and services on the city platform.
- Migrate legacy systems to the new architecture.
- Interconnect not migrated legacy systems to the city platform.

Figure 61: Applications over a service-oriented IT architecture



In low-resource environments, reducing costs, eliminating duplicate systems, and avoiding inefficiencies in coordination tasks should be a priority, given that this would allow additional resources to be obtained to advance in the transformation and digitalization of the services provided to citizens.

Within the reference architecture described in chapters 4 & 6, the data-knowledge layer and the common services-support layer of the City Platform allow functional blocks that can be used in the design of applications and digital services for citizens, generating efficiencies and cost savings.

Database management, database processing, or geospatial management tools are examples of these.

At this point, for the development and deployment of applications, mainly for citizens, the city should identify open and re-usable digital solutions with a "Building Block" approach. Examples of this can be the blocks that offer services capable of electronically identifying users, creating and verifying an electronic signature, exchanging electronic data and means of payment, and so on.

8.3.4 ICT Evolution

The process of digital transformation of an SSC is a task that will depend largely on the existing ICT infrastructure, costs and operational needs of the city. Most of the city ICT departments already have technological evolution plans in which the support to the operation is contemplated, as well as the evolution to satisfy the operational needs in the short and medium term. However, it is not very common for these departments to consider specific elements of smart and sustainable cities such as, for example, the management of IoT devices, and Big Data systems.

A large part of the recommendations described below are already implemented to a greater or lesser extent in cities, but they have been included because they are essential pieces in an SSC.

1. Elaboration of the strategic formulation of the city that includes the vision and objectives of transformation, as well as tractor projects that support the transformation of services and the focus on the citizen, towards an SSC.
2. The implementation of a **City Platform** could be a starting point for transformation in city ICT area. Its implementation does not initially interfere with existing systems and does provide the necessary capabilities to obtain information from IoT devices and analytical tools that are not generally available in cities. This line of action translates into the following steps:

    - Starting with the definition and design of a City Platform to create a long-term city vision focused on the citizen and with a defined government, which facilitates innovation, transparency and access to data.
    - Implementation of a City Platform with an architecture based on open standards & APIs, which allows interoperability, with maximum data security, and promote its adoption and use within the City Council itself.
    - Integrate all the sensors that will be deployed in the city. The City Platform will allow the ingestion of data from any device that meets communication standards.
    - Connect City Platforms with city systems to obtain data of interest.
    - Development of sustainable services that contribute to the improvement of municipal services.

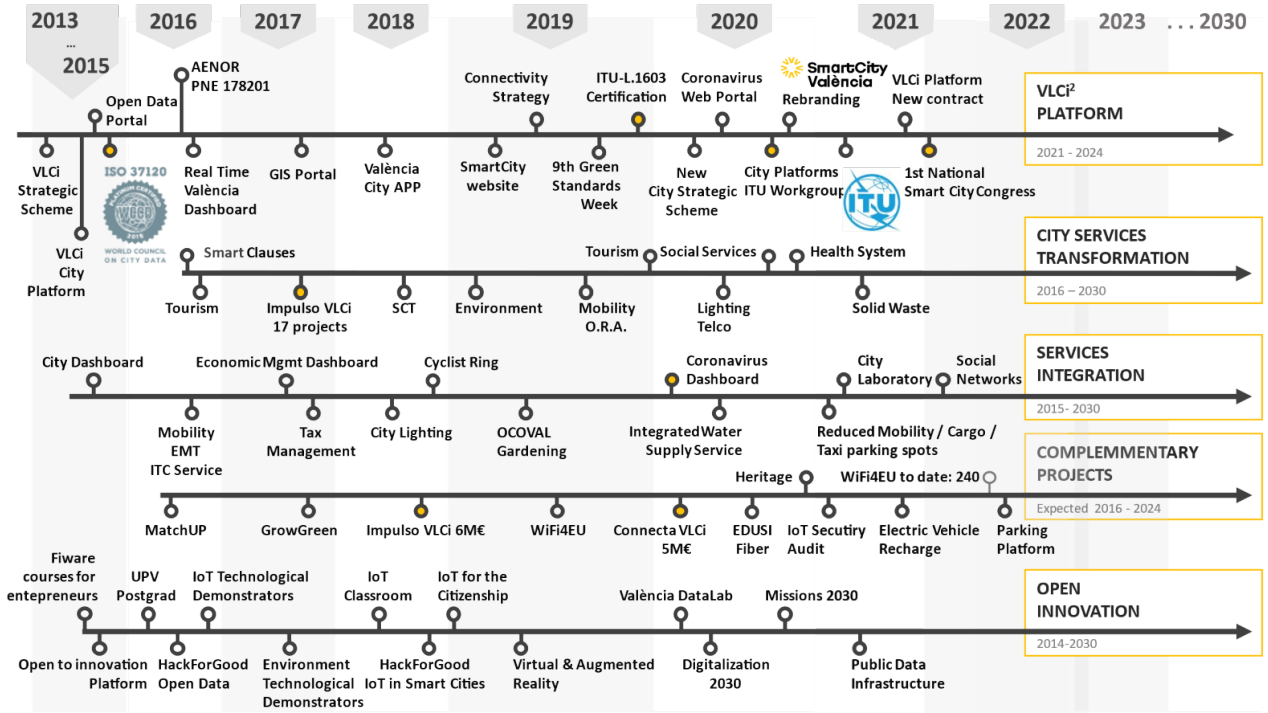
3. Implement a consistent **set of KPI's** based on international recommendations (U4SSC, SDG-11) to monitor and evaluate city transformation to an SSC.
4. Implement a **service-oriented architecture** that allows the creation of microservices, which can be orchestrated, and can be communicated through an integration bus that allows interoperation complying with security mechanisms.
5. Develop the main **corporate databases** of a city: territory, organization, citizens (also companies). These databases must be created with the principles of security and interoperability by design.
6. Implement a municipal, **corporate geographic information system** to geolocate all the assets of the city in the territory. Enable municipal services so that their daily management can be developed on this platform.
7. Implement **electronic identity for citizens and municipal officials**, for electronic identification and for the authorship of electronic documents.
8. **Review**, from an electronic management point of view, **the administrative procedures of the city**. Realization of an application of catalogue of procedures that allows the management of the services: who can request it, documentation to be presented, actions to be carried out by the applicant, resolution period, and so on.
9. Define and implement the **electronic documentation and recording system** in the city through the implementation of a corporate document management tool. Define metadata, typology, conversion and copies, format, and document filing. In the case of the file: index, its integrity, actions and administrative tasks.
10. Develop a **certified digitization application** to digitize paper documents with legal guarantees, as well as a corporate signature holder integrated with the organizational database for the electronic signature of electronic documents issued by municipal officials.
11. **Develop citizen-centric applications** to improve electronic citizenship relations through the electronic office, for example initiation of administrative procedures, citizen folder, validation of electronic documents, status, documentation, and electronic notifications.
12. **Develop an open data portal and city dashboards** to improve transparency.
13. **Develop a *"City App"*** using the functionalities of GIS and the data platform.
14. **Develop internal dashboards** to improve the strategic and operational decisions of those responsible for the city, as well as to measure and monitor sustainable and Smart City indicators.
15. **Develop tractor and complementary projects** (quick wins also) with collaboration of stakeholders.
16. **Communicate** internally and to citizenship SSC achievements. Engage citizen and civil servant on training in ICT technologies.
17. Implement a **continuous evaluation** of the entire process.

8.4 Milestones and lines of action along the path of transforming Valencia into an SSC

Valencia (Spain) contributed to establish in 2012 the Spanish Smart City Network (RECI) and, in 2014, started its own transformation project into a Smart and Sustainable City (VLCi) with the elaboration of a first strategic formulation and the commissioning of a city platform as the backbone of the digital and global transformation strategy.

Figure 62 shows the main milestones achieved during this time, as well as the lines of action on which the city's strategy is articulated, which in 2022 was updated to adapt it to the new challenges.

Figure 62: Main milestones València Smart City



- **VLCi platform and City strategy**: Collaboration with the Spanish Network of Smart Cities (RECI) and with different national and international standardization bodies (UNE PNE-178201, ITU-T Y.4201, ITU-T Y.4200, ITU-T L.1603), obtaining ISO 37120 and U4SSC KPI's certifications and the leadership of the U4SSC Thematic Group on City Platforms. Additionally, Open Data Portal; Unified and City Dashboards; integration with the geographic information system (geoportal); consolidation of personalized services in the city app (AppValència); connectivity strategy and city in telecommunications.
- **Integration of municipal services in the platform**: Different legacy systems have been connected to the city platform in order to obtain valuable data for the city. This integration began with the IT department, City Transport service, Sustainable Mobility, Tax Management, Street Lighting, Gardening, and others. Additionally, specific performance indicators have been defined to monitor the operation of these services.

- **Transformation of services**: The consultative strategy around the smart clauses (a set of KPIs to collect data via APIs of municipal contractors) have been introduced into different technical specifications: maintenance and conservation of buildings; cleaning of public schools and public nursery schools; home telecare service; supply, installation and maintenance of equipment for measuring air and noise pollution; maintenance service of the public lighting installation; regulated parking service on public roads; traffic management service; maintenance and cleaning service for the landscaped spaces, their facilities and equipment, as well as street trees.
- **Complementary projects:** The implementation of an integrated city management platform has been an advantage to obtain financing from national and European projects because data integration into the platform is a requirement of such projects. The most important projects in which the integration into the VLCi platform has already begun are Matchup, Growgreen, IMPULSO VLCi and Connecta VLCi (see Valencia smart city web page).[70]
- **Open Innovation**: The constitution of the platform as the main element of innovation towards the research and entrepreneurship sector of our socio-economic outline has been developed through a series of actions – including courses, hackathons, demonstrators, classrooms and laboratories – that have made it possible to obtain research projects and new Smart City application products.

Endnotes

1 United for Smart Sustainable Cities (U4SSC), Thematic Group on City Platforms, available at: https://u4ssc.itu.int/city-platforms/

2 Toolkit on Digital Transformation for People-Oriented Cities and Communities, available at: ITU-T, https://toolkit-dt4c.itu.int/

3 Chu, P-Y & Tseng, H-L. (2018). Open Data in Support of E-governance Evaluation: A Public Value Framework. ICEGOV '18: Proceedings of the 11th International Conference on Theory and Practice of Electronic Governance. 338-343. 10.1145/3209415.3209433

4 Osborne, S. P., Nasi, G., & Powell, M. (2021). Beyond co- production: value creation and public services. Public Administration.

5 State of the Art Report, 2021 (Drawn from Chu and Seng, 2018; Moore, 1995; Barcevičius and others (2019); and Osborne and others (2021)

6 ITU in the UN Environmental agenda, available at: https://www.itu.int/en/action/environment-and-climate-change/Pages/ITU-in-the-UN-Environmental-Agenda.aspx

7 WMO Guidance on Integrated Urban Hydrometeorological, Climate and Environmental Services. WMO-No. 1234: Volume 1: Concept and Methodology, 2019. Available at: https://library.wmo.int/doc_num.php?explnum_id=9903

8 Creutzig, F., Lohrey, S., Bai, X. et al., 2019. Upscaling urban data science for global climate solutions. Global Sustain. 2 (e2), 1–25. https://doi.org/10.1017/sus.2018.16.

9 Implementing Sustainable Development Goal 11 by connecting sustainability policies and urban planning practices through ICTs. U4SSC Series Document - ITU.

10 Available at: https://sdgs.un.org/un-system-sdg-implementation/international-telecommunication-union-itu-24522

11 Hassankhani M, Alidadi M, Sharifi A, Azhdari A. Smart City and Crisis Management: Lessons for the COVID-19 Pandemic. Int J Environ Res Public Health. 2021 Jul 21;18(15):7736. doi: 10.3390/ijerph18157736.

12 Available at: https://assets.kpmg/content/dam/kpmg/au/pdf/2020/smart-city-transformation-in-post-covid-world.pdf

13 ITU-T Y.4903 : Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals (03/2022), available at: https://www.itu.int/rec/T-REC-Y.4903-202203-I/en

14 Berlin declaration digital society and value based digital government, available at: https://digital-strategy.ec.europa.eu/en/news/berlin-declaration-digital-society-and-value-based-digital-government

15 Tallin declaration, available at: https://wayback.archive-it.org/12090/20200911081915/https://ec.europa.eu/digital-single-market/en/news/ministerial-declaration-egovernment-tallinn-declaration

16 ITU Secretary-General's report for the Sixth World Telecommunication/Information and Communication Technology Policy Forum 2021 https://www.itu.int/md/S21-WTPF21-C-0003/en

17 British Standards Institution (BSI) PAS 181:2014 Smart City framework, 2014.

18 British Standards Institution (BSI) PAS 182:2014 Smart City concept model, Guide to establishing a model for data interoperability, 2014.

19 ITU-T, 5G-fifth-generation-of-mobile-technologies, available at: https://www.itu.int/en/mediacentre/backgrounders/Pages/5G-fifth-generation-of-mobile-technologies.aspx

20 ITU-T, IoT, available at: https://www.itu.int/en/ITU-T/gsi/iot/Pages/default.aspx

21 3GPP TS 22.368 Service requirements for Machine-Type Communications (MTC) V16.0.0 (07/2020).

22 3GPP TR 45.820 Cellular system support for ultra-low complexity and low throughput Internet of Things.

[23] ITU-T Recommendation ITU-T Y.4200 (02/2018), Requirements for the interoperability of Smart City platforms.

[24] ITU-T Recommendation ITU-T Y.4201 (02/2018), High-level requirements and reference framework of Smart City platforms.

[25] IoT Analytics Research, May 2022, https://iot-analytics.com/number-connected-iot-devices/

[26] ITU-T Focus Group on St Sustainable Cities, Cybersecurity, data protection and cyber-resilience in sustainable cities (03/2015).

[27] ITU-T Recommendation Y.2001- Next Generation Networks General Overview.

[28] ITU-T Recommendation Y.2011- Next Generation Networks – Frameworks and functional architecture models. General principles and general reference model for Next Generation Networks.

[29] ITU-T Recommendation Y.1541, Quality of service and network performance, Network performance objectives for IP-based services (12/2011).

[30] ITU-T Recommendation Y.2617, Quality of service guaranteed mechanisms and performance model for public packet telecommunication data networks (06/2016).

[31] 3GPP TS 22.368 Service requirements for Machine-Type Communications (MTC) V16.0.0 (07/2020).

[32] ITU-T Q.3925 Testing for next generation networks, Traffic flow types for testing quality of service parameters on model networks (03/2012).

[33] ITU-T Recommendation Y.2011- Next Generation Networks – Frameworks and functional architecture models. General principles and general reference model for Next Generation Networks.

[34] Unified communications, What new businesses need to know; microsoft.com; https://www.microsoft.com/en-us/microsoft-365/business-insights-ideas/resources/unified-communications-101-what-new-business-need-to-know

[35] Hybrid Work Index (Cisco); https://www.cisco.com/c/en/us/solutions/executive-perspectives/hybrid-work-index.html?ccid=cc002463

[36] E. S. Alias, M. Mukhtar and R. Jenal, "Embedding key user values for the adoption of unified communication and collaboration service", in proc. 6th International Conference on Electrical Engineering and Informatics (ICEEI), Langkawi, 2017, pp. 1-4, 10.1109/ICEEI.2017.8312412.

[37] The Rise Of Unified Communication And Collaboration Tools In The COVID-19 Era (forbes.com) https://www.forbes.com/sites/forbescommunicationscouncil/2021/05/06/the-rise-of-unified-communication-and-collaboration-tools-in-the-covid-19-era/?sh=68610f485ed5

[38] IEEE 1901-2020 - IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications.

[39] ITU-T Recommendation ITU-T G.709/ Y.1331 (06/2020) Interfaces for the optical transport network.

[40] https://www.mef.net/

[41] ITU-T Recommendation ITU-T G.984 (03/2008) Gigabit-capable passive optical networks (GPON): General characteristics.

[42] VPN & SDN services catalogue, Movistar, https://www.movistar.es/grandes-empresas/soluciones/fichas/vpn-y-sdn/

[43] Projects of transformation towards the Smart City - València Smart City (valencia.es) https://smartcity.valencia.es/projects/

[44] RODRIGUEZ-HERNANDEZ, Miguel A.; GOMEZ-SACRISTAN, Angel; GOMEZ-CUADRADO, David. Simulcity: Planning communications in smart cities. *IEEE Access*, 2019, vol. 7, p. 46870-46884.

[45] U4SSC Digital solutions for integrated city management and use cases, (Dec. 2021), ISBN: 978-9261348212

[46] ITU-T Recommendation ITU-T Y.4201 (02/2018), High-level requirements and reference framework of Smart City platforms.

47 ITU-T Recommendation ITU-T Y.4200 (02/2018), Requirements for the interoperability of Smart City platforms.

48 Available at:https://www.ontsi.es/sites/ontsi/files/interoperabilidad_parte_1_introduccion.pdf

49 Available at: https://www.fiware.org/about-us/

50 From GovStack & From Digital Investment Framework Annex 4

51 Available at: https://digitalimpactalliance.org/wp-content/uploads/2019/04/D-STR-DIGITAL.02-2019-PDF-E.pdf

52 Available at: https://ec.europa.eu/digital-building-blocks/wikis/display/DIGITAL/About+us

53 Available at: https://ec.europa.eu/digital-building-blocks/wikis/display/DIGITAL/Digital+Homepage

54 Available at: https://negd.gov.in/sites/default/files/IndEAdocument.pdf

55 Available at: https://www.indiastack.org/

56 Available at: SDG Digital Investment Framework," pg. 11 (DIAL and ITU, 2019)].

57 Available at: digfingroup.com/what-is-india-stack

58 Available at: negd.gov.in/india-enterprise-architecture

59 Available at: negd.gov.in/india-enterprise-architecture

60 Available at: https://smartnet.niua.org/sites/default/files/resources/nuis_master_doc_07.01.19_v5_0.pdf

61 Indian Standard IS 18006 (Part 1), 2021 Municipal Governance Reference Architecture.

62 Available at: https://www.segittur.es/en/

63 Available at: https://www.destinosinteligentes.es/en/

64 United for Smart Sustainable Cities (U4SSC), Thematic Group on City Platforms, available at: https://u4ssc.itu.int/city-platforms/

65 UNWTO's recommendations on urban tourism World Tourism Organization (2020), UNWTO Recommendations on Urban Tourism, UNWTO, Madrid, DOI: https://doi.org/10.18111/9789284422012

66 Available at: https://www.itu.int/en/publications/Documents/tsb/2021-U4SSC-Compendium-of-survey-results/files/downloads/21-00562_U4SSC_Compendium%20of%20survey%20results.pdf

67 UNE 178201-2 Systems for managing Smart Cities and Balanced scorecard indicators https://www.en.aenor.com/certificacion/administracion-publica/ciudad-inteligente-indicadores

68 U4SSC, Collection Methodology for KPI, https://u4ssc.itu.int/u4ssc-kpis-report/available at: https://u4ssc.itu.int/u4ssc-kpi/

69 U4SSC, Thematic Group on City Platforms, available at: https://u4ssc.itu.int/city-platforms/

70 Valencia Smart City Office Web Page, available at: https://smartcity.valencia.es/en/

For more information,
please contact: u4ssc@itu.int
Website: https://u4ssc.itu.int/

ISBN: 978-92-61-37811-0

9 789261 378110

Published in Switzerland
Geneva, 2023

Photo credits: Adobe Stock