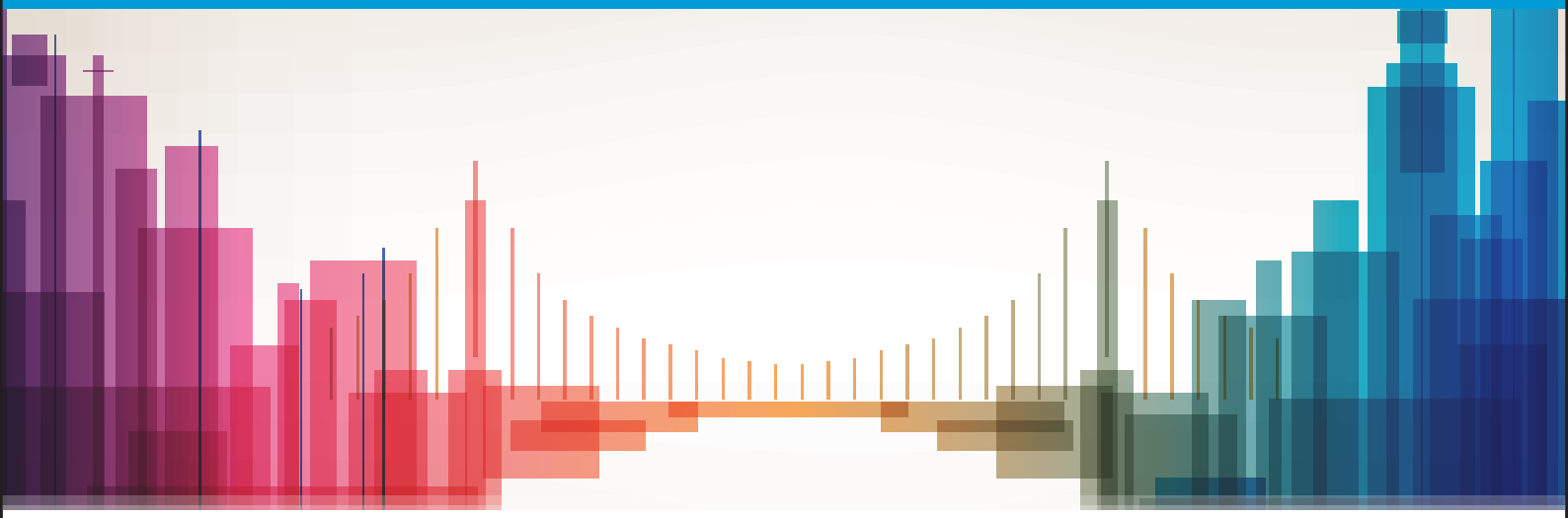
United 4 Smart Sustainable Cities

Digital solutions for integrated city management and use cases

A U4SSC deliverable on city platforms



Convention on Biological Diversity

United Nations ECLAC

Food and Agriculture Organization of the United Nations

ITU

UNDP Empowered lives. Resilient nations.

United Nations Economic Commission for Africa

UNECE

UNESCO United Nations Educational, Scientific and Cultural Organization

UN environment programme

UNEP FINANCE INITIATIVE

United Nations Framework Convention on Climate Change

UN-HABITAT FOR A BETTER URBAN FUTURE

UNIDO

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WORLD METEOROLOGICAL ORGANIZATION


5G

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Foreword

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

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An accompanying Compendium has also been published, which underscores the survey results provided by cities that have collaborated describing their transformation experience through the use of a city platform.

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 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, interviews and voluntary written contributions from stakeholders.

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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 14 other UN bodies.

Smart city platforms are becoming a new digital urban infrastructure that facilitates the implementation of smart city strategies to support new and additional city needs, while also assisting with the efforts of addressing targets contained in the Sustainable Development Goals (SDGs). Smart city platforms provide cities with a technological base to incorporate a multitude of elements that can enable a city's digital transformation to help achieve the city's internal objectives, facilitate informed decision-making by policy-makers, and promote cost-efficient and effective city operations. It has served as the blueprint for evolution, supporting the transition from fragmented urban operations to integrated management with data as the main asset.

Complex challenges facing cities, such as the Covid-19 pandemic, require managing information from multiple areas of the city as well as from other institutions and private entities. Smart city platforms include IT elements for interoperability of services, which are necessary to face these challenges. This report provides a global perspective on how city platforms facilitate more efficient and effective control of public infrastructure and services, improve economic efficiencies, enable rapid development of new or complex services and play a critical role in the overall digital transformation of urban areas.

A layered model of the reference technological architecture, as well as the enabling solutions, has been illustrated in this report with the aim of briefly underscoring the basic functionality of the common components or elements that constitute a city platform. In addition, reference is made to the different regulations existing and contained in international instruments. The experience of certain cities with the implementation and operation of city platforms is a prominent feature of this report.

The description of core challenges faced by cities in strategic, technical, and operational aspects, as well as the barriers encountered in the implementation of the city platforms, are adequately elaborated on in order to provide interested stakeholders with additional guidance on commencing their respective smart city journeys. Furthermore, the report concludes by outlining the technical and non-technical challenges that cities are still facing when implementing the envisioned platforms along with the pivotal role of international standardization in addressing them.

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List of Abbreviations

ACC	Auric Command and Control Centre
ADIF	Administration of Railway Infrastructures
AENA	Spanish Airports and Area Navigation
AENOR	Spanish Association for Standardization
AP	Access Point
API	Application Programming Interface
BIM	Building Information Modelling
BMS	Building Management System
CBD	Central Business District
CCTV	Closed-circuit Television
CCPA	California Consumer Privacy Act
CEF	Connect Europe Facility
CIM	Civil information modelling
CP	City Platform
DIN	German Institute of Standardization
EIP-SCC	European Innovation Partnership on Smart Cities and Communities
EMT	Municipal Transport Company
ETLs	Extract Transform Load
EU	European Union
GDPR	General Data Protection Regulation
GIS	Geographic information system
GQOL	Global Quality of Life
H2M	Human to Machine
ICC	Integral Control Centre
iCP	Intelligent City Platform
ICTs	Information and communication technologies
ID	Digital Identity
IEC	International Electrotechnical Commission
IoT	Internet of Things
ISO	International Organization for Standardization
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LED	Light Emitting Diode
LPWAN	Low Power WAN
M2M	Machine to Machine
MIMO	Multiple-Input and Multiple-Output
PLC	Power-Line Communication

PPP	Public Private Partnership
PRM	Person with Reduced Mobility
RCMS	Remote Control and Monitoring System
RECI	Spanish Smart City Network
ROI	Return on Investment
SCADA	Supervisory control and data acquisition
SCP	Smart City Platform
SDGs	Sustainable Development Goals
SDO	Standards Developing Organization
SDP	Smart Dubai Platform
SME	Small and Medium-sized enterprises
SNSP	Singapore's Smart Nation Sensor Platform
SSC	Smart Sustainable Cities
U4SSC	United for Smart Sustainable Cities
UAE	United Arab Emirates
UK	United Kingdom
UNE	Spanish standardization Body
UNECE	United Nations Economic Commission for Europe
UDP	Urban Data Platform
US	United States
USA	United States of America

1 Introduction

1.1 Context and background

Since first mainstreaming in the early 1990s, the "*Smart City*" concept has transitioned from the use of information technology to help address cities' needs, to also include a focus on sustainability[1] – along with resilience, inclusiveness, citizen engagement, and participation. This transition has occurred, in large part, due to the rise of new digital technologies, such as Artificial Intelligence, BlockChain, Cloud Computing, and the Internet of Things (IoT). Smart embedded devices can provide city managers of real-time spatial, economic, and environmental data for improved and agile decision-making. The city data platform infrastructure is a key element of this transformation that assures seamless communication between heterogeneous systems and technologies.

The International Telecommunication Union (ITU) – the United Nations specialized agency for information and communication technologies (ICTs) – has accordingly put forth the concept of "Smart Sustainable Cities" (SSC) in conjunction with other UN bodies.

Smart sustainable cities are defined in the Recommendation ITU-T Y.4900: "Overview of key performance indicators in smart sustainable cities":

> *"A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, 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."*

City competitiveness in the definition above refers to "policies, institutions, strategies, processes (and innovation) that determine the city's sustainable productivity"[2].

Smart sustainable cities successfully adopt advanced forms of digital technologies and ICTs to improve their performance in line with the Sustainable Development Goals (SDGs) and the requirements of urban growth and technological proliferation. In doing so strategically, they tap into the tremendous potential that exists to enhance urban operations, functions, services, designs, strategies, and policies for the benefit of citizens and the environment.

Smart sustainable cities do this, in part, by combining the role of ICTs as the platform for the aggregation of information and data (city platform) with traditional infrastructures. ICTs in smart sustainable cities provide valuable insights into how the city functions in terms of resource consumption and services.

ICT-based urban services in smart sustainable cities provide some benefits related to[3]:

- Improving energy efficiency.
- Operation and transparency of the urban infrastructure.
- Resilience of mobility networks.
- Efficiency of water distribution systems.
- Wastewater management.
- Security.
- Other services.

Moreover, ICTs should not only establish defined urban functions in smart sustainable cities, but also help foster engagement during the designing and planning process for cities among citizens, governments, enterprises, and other stakeholders. This engagement is expected to facilitate participation and shared knowledge for urban governance, which is essential for keeping the city's future designs for economic, social and environmental development in line with a credible smart sustainable vision.

Even with this definition and understanding of a smart sustainable city, the manifestation of it varies by city, country and region, depending on the city's level of development, cultural attitudes to change, financial resources, technical landscape and capabilities, and overall aspirations. A *smart sustainable city* in Africa would be unique to that country and the region's context in comparison to its counterpart in the Latin American, South Asian or North American context.

ITU-T helps to build Smart Cities in many different ways as show in Fig 1:

- Internet of Things (IoT) to enable the coordinated development of interoperable technologies.
- Big Data to define the specific capabilities required to manage massive and complex data streams.
- 5G systems as critical infrastructure to handle the demands of fast data in real time.
- Technical Standards to harmonize and protect key ICT infrastructure investments.
- Spectrum allocation to assure interference-free wireless telecommunications.

Figure 1: How ITU-T helps build smart cities[3]

It is important, therefore, to understand – especially from a technology deployment perspective – the major aspects and themes that smart cities can be classified by.

1.2 Smart city typology

Transitioning to a smart city impacts the different areas of the city management model and encourages the designing of public policies aligned with this transformation. Although there are varied approaches in literature and international standards [4], it is commonly acknowledged that smart cities could comprise four aspects[5]:

1. **Smart Infrastructure** to connect physical objects and sensors through heterogeneous communication networks, realizing the interconnections between human and machines (H2M) and between machines (M2M).
2. **Smart Operations** for improving the citizens' quality of life, by offering innovative services in every business sector and integrating application systems and information, to be the core elements supporting urban operation and management.

3 **Smart Ecosystem** where the analysis of the interconnected information should yield new insights for driving decisions and actions that improve process outcomes of systems, organizations, and industry value chains.

4 **Smart Governance** to facilitate the interconnection of urban components accompanied by integrated application systems that need to be supported by urban scale management with the coordination of urban critical systems to make a city run efficiently and in a smart manner.

Recommendation ITU-T Y.4900 outlines the main aspects of *smartness* through the lens of *sustainability*. According to this international ITU standard, the *sustainability* of a smart city is based on four main aspects[6]:

- **Economic:** The ability to generate income and employment for the livelihood of the inhabitants.
- **Social:** The ability to ensure that the welfare (safety, health, education) of the citizens can be equally delivered despite differences in class, race or gender.
- **Environmental:** The ability to protect future quality and reproducibility of natural resources.
- **Governance:** The ability to maintain social conditions of stability, democracy, participation and justice.

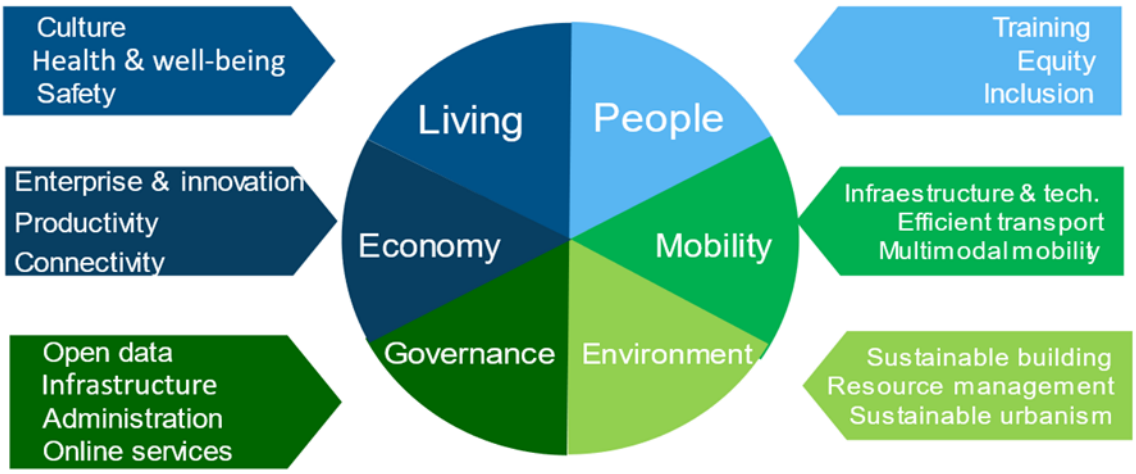
IEEE Standards also chart the domains relating to smart cities aiming at guiding humanity and serving the citizens (see Figure 2). Some of the vertical standards include[7]:

- Smart Grid
- Transportation
- Digital Health
- Infrastructure Management
- Industrial Automation/Smart Factory
- Smart Home

Figure 2: Domains within smart cities (Redrawn from IEEE perspective)

Other approaches derive from the six common smart city dimensions (see Figure 3).

Figure 3: The six dimensions of a smart city[8]



1.3 Smart city sustainability and SDG objectives

Resources, in general, are limited and therefore are usually configured for a stable environment. Any major crisis could 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 aim of the efforts of public administrations. In this section, information management and interoperability are key aspects.

Since 2015, the United Nations 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) have been driving and inspiring governments and other stakeholders to take transformative actions, both individually and collectively, for people, the planet, and prosperity.

For cities and communities, Goal 11 refers to "Make cities inclusive, safe, resilient and sustainable[9]". To meet the targets stipulated within SDG11, there is a need to:

- Take an active interest in the governance and management of the city.
- Identify what works and what does not work.
- Develop a vision for its buildings, streets, and neighbourhoods, and subsequently act on that vision.

Developments concerning job creation, health care, safety and security, mobility, environmental quality, shared public spaces, and citizen welfare are all interrelated, and concerns about them motivate city administrations to meet SDG 11. In that sense, an efficient holistic management approach for creating a vision for implementing and improving action plans, with relevant key performance indicators (KPIs), is an efficient technique to meet the objectives and improve the global quality of life.

While "privacy" is an important aspect to be taken into consideration for the establishment of a smart city platform, there should be a trade-off between privacy and citizen privacy rights.

1.4 International standards in the homogenization of city indicators

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 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 inclusion of standardized indicators in the dashboards of urban city platforms can be used to measure and evaluate city performance to:

- Monitor and evaluate the progress in urban development and ongoing projects.
- Measure changes in the city after the implementation of its smart city project.

- Compare the existing situation (baseline) with the expected impact.
- Compare projects with each other while tracking the performance one's own projects.
- Track the progress concerning the overall policy goals of a city and provide a benchmark for comparing cities with each other.

2 Common smart city technology challenges

While smart city technologies have tremendous potential to assist cities in 'leapfrogging' outmoded economic and social activities, these technologies are not a panacea. Their success in ensuring sustainable development calls for strategic solutions, government support, inclusive innovation engaging all stakeholders, global access to new technological capabilities, and applications of these technologies at the scale necessary to achieve sustainable impact.

Aside from any ongoing security, privacy and accessibility challenges or concerns, common challenges related to smart city technologies from a deployment viewpoint include the following[10]:

1. **Scalability:** With smart devices in cities increasing rapidly and sensor networks becoming concurrently diverse, scalability is a technical challenge to enabling ubiquitous access. In essence, smart city applications encounter major scalability problems due to the large amount of data they must process. A city platform can be considered scalable when it demonstrates the ability to adapt to IoT or Industry 4.0 models, standards and requirements.
2. **Legacy technology:** As the demand for new services keeps increasing in smart cities, retaining old technologies becomes infeasible and developers and service providers must create afresh instead of reusing and customizing older technologies. When retained, older technologies still need to meet scalability and efficiency requirements at different levels, including naming and addressing, communication and networking, data management, and service provisioning.
3. **Governance:** *Smart sustainable cities*, by definition, engage and involve several different types of stakeholders within both the technology products and services realm. In the absence of flexible horizontal solutions for sharing skills, network infrastructures, and devices between the various technology provision and management stakeholders, governance can be a challenge.
4. **Lack of testbeds:** Cities need to ensure reliability when it comes to city-wide technology deployment. Typical testbeds only offer experimentation and testing limited to specific environments or application-specific deployments and allow for neither conclusive experimentation nor test for all constraints to do with non-technical stakeholders. When it comes to IoT deployment especially, largescale testbeds are necessary.
5. **Interoperability**: Different providers use various smart city applications created by different developers to offer services to citizens. In fact, it is quite common in smart cities to use technologies based on proprietary solutions, which inhibit the communication and interoperation that is needed to function seamlessly to achieve efficient large-scale smart city solutions.

6 **Reuse**: The development of a largely or entirely new platform is a complicated and time-consuming effort. In contrast, the reuse and customization of old functionalities denote greater development efficiency.

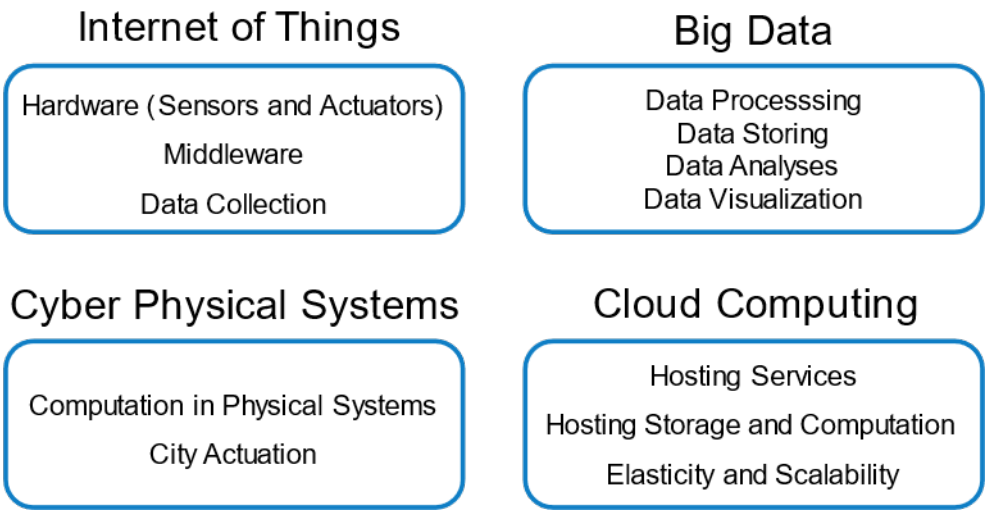
3 The need for smart city platforms

The different systems in a city context can be classified as internal systems (mostly related to traditional community services), like waste management, lighting, parking, and traffic control, and external systems, such as transport companies, ports, airports, buildings, hotels, and social networks[11].

These systems could give useful information about the state of a city and be managed through different types of control tools (IoT platforms, SCADA, non-IoT platforms, Big Data processors, etc.). However, as the challenges outlined in the previous section highlight, most of the time these control tools, where they exist, are independent, non-standard and without the possibility of sharing resources and data[12].

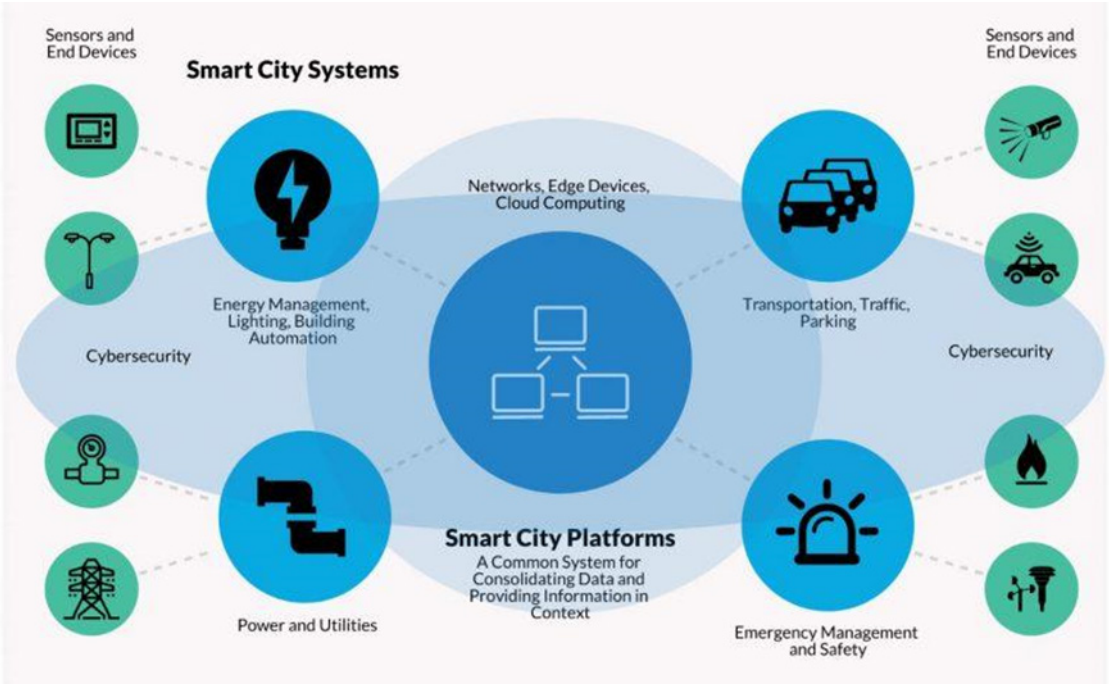
A general smart city platform solution is the answer to the need for an integrated and managed system that assures seamless communication between heterogeneous systems and technologies. It is typically built on some common enabling subsystems. The four main ones used by platforms for smart cities being: Cyber-Physical Systems, Internet of Things (IoT), Big Data, and Cloud Computing[13] (see Figure 4). The type of technology also dictates the requirements that the platform must address.

Figure 4: Smart city platform enabling technologies



The ability to integrate and utilize data from multiple smart city systems or solutions is a defining criterion of a city platform. This concept is illustrated in the following Figure 5.

Figure 5: Typical view of integration by a smart city platform[14]



Regardless of the underlying technology or mix of technologies, to be successful in its intended purpose, the city platform should:

1 Have a modular design, where each module manages a different element of the smart city.

2 Allow for organization, transparency, flexibility and scalability in terms of its design.

3 Be capable of interacting with both human beings (H2M) and computers or machines (M2M).

4 Be able to collect and process vast volumes of various types of high-velocity data autonomously, including in real time, from multiple and third-party sources.

5 Bring together different information systems, devices and applications in the city to communicate, and to exchange data accurately, effectively and consistently.

6 Allow for the data that flows in to be processed and analysed to generate actionable insights and sound decisions.

Moreover, expanding on point No. 5 (relating to information systems), the following aspects[15] are required of a city platform to ensure adequate interoperability:

1 **Interoperability with different technologies**: refers to the capability of supporting different technologies for capturing information and communications standards as well as internal/ corporate and/or external information systems.

2 **Performance**: refers to the ability to handle a large number of devices, services and processes efficiently.

3 **Scalability**: pertains to the ability to increase processing, interconnection and storage capacities without needing to change the architecture.

4 **Robustness and resilience**: refer to the capability to continue operation even while facing problems.

5 **Security**: involves guaranteeing security, integrity and reliability.

6 **Extensibility**: refers to adaptability to meet new needs.

3.1 Technological architecture of a city platform

City platforms are mainly based on international and national standards, such as ITU-T Y.4201, ISO/IEC 24039, UNE 178104: 2017, DIN 91357-2017, and FIWARE. These standards have an architecture based on layers in common, where the different capacities planned for a City Platform are grouped together.

In general, the layers (although abiding by different nomenclatures depending on the standard) are commonly the following:

1 Acquisition and Integration of data from information systems and IoT devices

This layer concentrates the functionality that allows the integration of diverse data sources from different data collection systems. It is capable of integrating information from multiple sources: IoT sensors deployed by the city (traffic lights, street lights, park irrigation, temperature, capacity, etc.); information systems and external infrastructure; citizen devices (mobile APP) and social networks.

It is recommended that the data acquisition and formatting processes that collect field information be carried out using standard and open protocols, which results in scalability and ease in semantic abstraction protocols[16].

This layer also supplies information to the data/knowledge functions independently from the devices and formats the acquired data according to semantic processing. The acquisition/interconnection functions are independent of network information and control.

2 Information processing and data analysis

This layer, also known as Data/knowledge layer, includes the elements of information treatment, management, and exploitation. It includes the data repository that centralizes all data information, real-time repository, Big Data repository, and Geographic Information System (GIS).

The smart city platform should integrate software and tools to deal with data management and processing, data mining, engineering analysis, system control, machine learning, environmental assessment, and economic and social analyses. These tools should be able to share data and information among the city stakeholders. The platform should also integrate powerful modelling tools, such as GIS, Civil Information Modelling (CIM) and Building Information Modelling (BIM). In some cases, the platforms should integrate Big Data analysis tools.

3 Interoperability and integration

This layer allows interconnection between applications and with other platforms. The city platform, through the Interoperability layer, provides standard and open interfaces that guarantee the sending of data by devices and other information systems and access to them by different applications, both in real time and deferred.

Effective Open Data must be structured around well-defined standards and accompanied by the corresponding metadata, and it must be made available in files in standard formats or via well-defined APIs. The license associated data must clearly state whether it can be shared and freely used by third parties. Finally, proper care must be taken about the privacy of citizens, applying anonymization techniques whenever needed[17].

4 Vertical services layer

Business applications and services are deployed on a layer of different vertical components, including the management and control of the elements of the city platform that are used in the verticals. Applications can be running on the platform or there can be other external services that publish or use the information.

The interaction and involvement of stakeholders is at the heart of the *smart city concept*. The platform should integrate specific tools to interact with citizens, the administration, service providers, professionals, and visitors, using the opportunity to diffuse information to different groups (social communities) while also receiving information, feedback and requests from the city stakeholders.

5 Security management and support layer

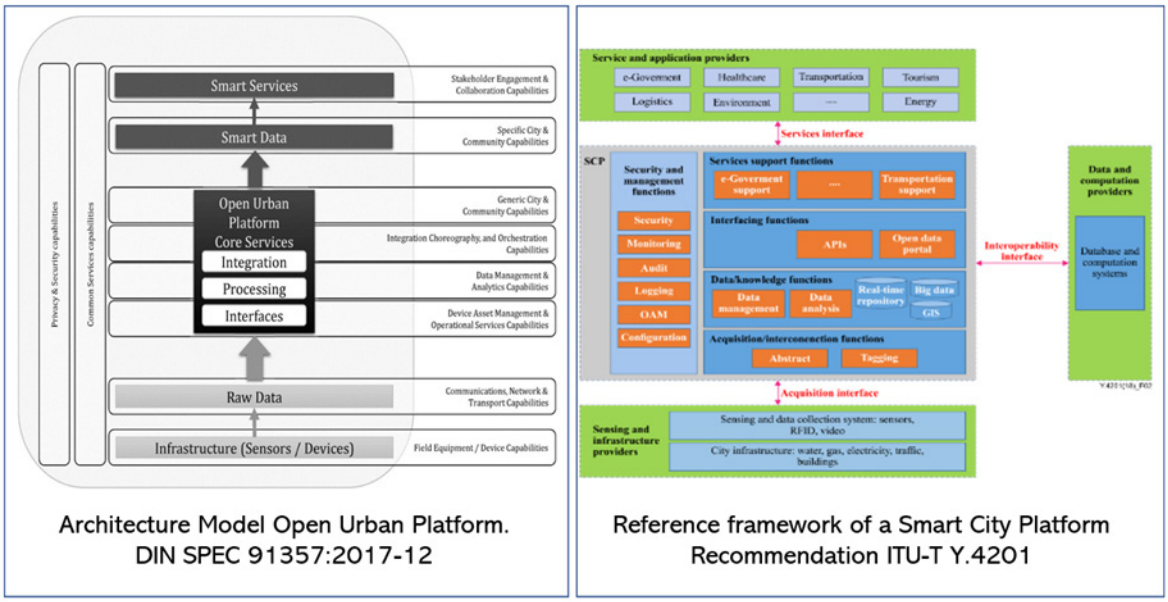
Urban/City Platforms must have a support layer that offers auditing, monitoring and security services. It must be able to receive, process, view, monitor and manage the different services and systems that are integrated, providing a single and centralized vision.

- Security: This provides security mechanisms, such as authentication, authorization, and ciphering.
- Monitoring: This collects platform operation information.
- Audit: This registers those who have accessed sensitive information.

- Logging: This traces the execution of the applications and/or the systems of the platform.
- Configuration: This allows access to the configuration of the systems and to change the execution parameters.
- Operation, administration and maintenance (OAM): Processes and tools that allow the platform to be operated, managed and maintained.

Figure 6 shows, as an example, two architecture models of a smart city platform.

Figure 6: Layers of a smart city platform



Architecture Model Open Urban Platform. DIN SPEC 91357:2017-12

Reference framework of a Smart City Platform Recommendation ITU-T Y.4201

3.2 Enabling solutions

The city platform serves as a technological base for a multitude of enabling elements of the city's digital transformation achieving its internal objectives, informed decision-making by policymakers, and cost-efficient and effective city operations.

City platforms provide various enabling tools to satisfy different purposes:

- The information systems of the different municipal departments are integrated into the city platforms. This allows obtaining data of interest from each department, managing it from a common repository. This information, in the form of KPIs, will serve for decision-making and for the self-evaluation of the municipal department itself. All this information is displayed on the dashboards for internal use by municipal managers.

- Unified management dashboards allow municipal departments to consult geo-referenced data and information of interest in the form of indicators, such as economic management, administrative tasks, traffic management, waste, and air quality. All of these should be broken down by each municipal department.
- Geographic Information Systems connected with city platforms provide geo-referenced information on existing resources in the city. This information is extracted from different municipal departments that report data through layers of geographic information as well as from companies contracted by the city council to perform different services. These systems have APIs for direct access to objects stored in the municipal geodatabase. This allows integration with third-party applications that require geospatial functionality.
- City apps are key elements that integrate all the information related to the city in a single environment, allowing citizens and visitors to consult the information of interest based on their geo-positioning and carry out procedures with the local administration, including smart services that the city council can provide. One relevant example could be in the domain of mobility services: In the interactive city map, they can find public transport, enable cycle hire, promote car-sharing services, and locate pedestrian paths[18].
- The creation of transparency and open data portals based on the data integrated into the city platforms makes it possible to provide all the information of the city available to citizens and companies in different formats, accessible through web portals, through open APIs and in real time.
- City platforms improve security for data privacy and security management because the information is contained in a centralized schema.
- City platforms could contribute to entrepreneurship and innovation, co-creation of city services, and citizen engagement. "Living Labs" initiatives using city platform services enable "4P helix" (Public-Private-People-Partnership) ecosystems that provide "opportunities to citizens and businesses to co-create, explore, experiment and validate innovative scenarios based on technology platforms, such as future internet experimental facilities".[19]
- City platforms also provide support for environmental sustainability or social objectives, such as liveability, reduced inequality, public health and poverty reduction.

4 The experiences of cities with smart city platforms

In this section, several state-of-the-art integrated smart city platforms are described through the cases of various cities, communities and municipalities. Some of the featured cities are part of United for Smart Sustainable Cities (U4SSC) (See Box 1).

Box 1: United for Smart Sustainable Cities (U4SSC)

The United for Smart Sustainable Cities initiative

Established in 2016, United for Smart Sustainable Cities (U4SSC) is a United Nations initiative coordinated by ITU, UNECE and UN-Habitat, and supported by 14 other United Nations entities. Since its creation, this initiative has been helping cities to achieve Sustainable Development Goal (SDG) 11: "Make cities and human settlements inclusive, safe, resilient and sustainable" by coupling key smart and sustainable city endeavours with the core targets stipulated within the 2030 Agenda for Sustainable Development. The activities of U4SSC are aligned with the New Urban Agenda, which is the latest guideline document of the bidecennial United Nations Conference on Housing and Sustainable Urban Development.

U4SSC serves as the global platform for advocating the formulation of public policy and encouraging the use of ICTs to facilitate the transition of cities to smart sustainable cities. It is a collaborative platform that seeks to develop innovative solutions and elevate best practices through an inclusive and participatory process.

U4SSC's work on smart sustainable cities spans several different areas. These areas are the focus of U4SSC's various thematic groups, which include the group on *City Platforms* that is responsible for this report.

The cases featured in this report (listed in Table 1) were collected through two means. First, research was conducted to identify examples of successful smart city platform deployments all across the world. Secondly, an elicitation exercise was conducted whereby cities, communities and municipalities participating in the U4SSC initiative were asked to detail 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).

Cities participating in U4SSC's KPI implementation have described the technological architecture of their main solutions and the different "smart" enabling components and solutions for citizens and municipal services. The respondents also described the technical, administrative and project management organization that supports their city's strategy as well as their competencies. They defined their strategic SSC direction, as demonstrated by their commitment to standards (both 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 relationship with their citizens, the innovation ecosystem and the networks they depend on for the design, sharing and replication of smart and sustainable city solutions.

Certain smart sustainable cities detailed their decision to not invest in a smart city platform. Their experiences are also part of the useful discoveries detailed in the following cases (organized by region), which present the findings of the research.

The following sections include highlights about the experience of the selected cities (across geographic regions), concerning their city platforms and other strategic aspects of interest. Additionally, the related compendium, which underscores the survey results provided by cities that have collaborated describing their transformation experience through the use of a city platform, includes the complete documentation provided by each city that participated in the elicitation exercise for the development of this report.

Table 1: List of case studies explored

Region	City (Country)	Key feature of the Smart city platform
EUROPE	Cambridge (United Kingdom)	Open data centric
	El Hierro (Spain)	IoT FIWARE based platform
	Gjøvik (Norway)	Currently, no explicit city platform for integrated management in place
	Lisbon (Portugal)	FIWARE based platform
		Open data gate
	Logroño (Spain)	Open data
	Pully (Switzerland)	Big Data
	Trento (Italy)	Digital data hub
	Rivas Vaciamadrid (Spain)	Transparency and Open Data Portal
	València (Spain)	FIWARE based platform
		Big Data
		Open Data Portal
ASIA AND PACIFIC, MIDDLE EAST AND AFRICA	Abu Dhabi (United Arab Emirates)	IoT-based solutions
	Auric City, Aurangabad (India)	Command and Control Centre
	Broken Hill (Australia)	IoT platform
	Dubai (United Arab Emirates)	Smart Dubai Platform:
		• Service enablement
		• Data orchestration
		• Application Provision
	Newcastle (Australia)	Open data sets
	Singapore	Smart Nation Sensor Platform:
	Shanghai (China)	City Brain architecture:
		• Data governance
		• Application ecosystem
		• Network infrastructure
		• System integration and collaboration

Region	City (Country)	Key feature of the Smart city platform
AMERICAS	Columbus (United States America)	Unified digital platform
	Kingston (Canada)	Pilot programmes include: • Energy management • Digital kiosks:
	Les Condes, Metropolitan Region (Santiago de Chile)	Open Smart City (Open Data)
	Markham (Canada)	Smart City Accelerator Research Programme
	Montevideo (Uruguay)	FIWARE based platform
	Orillia (Canada)	Digital kiosk (Open Data)

4.1 EUROPE

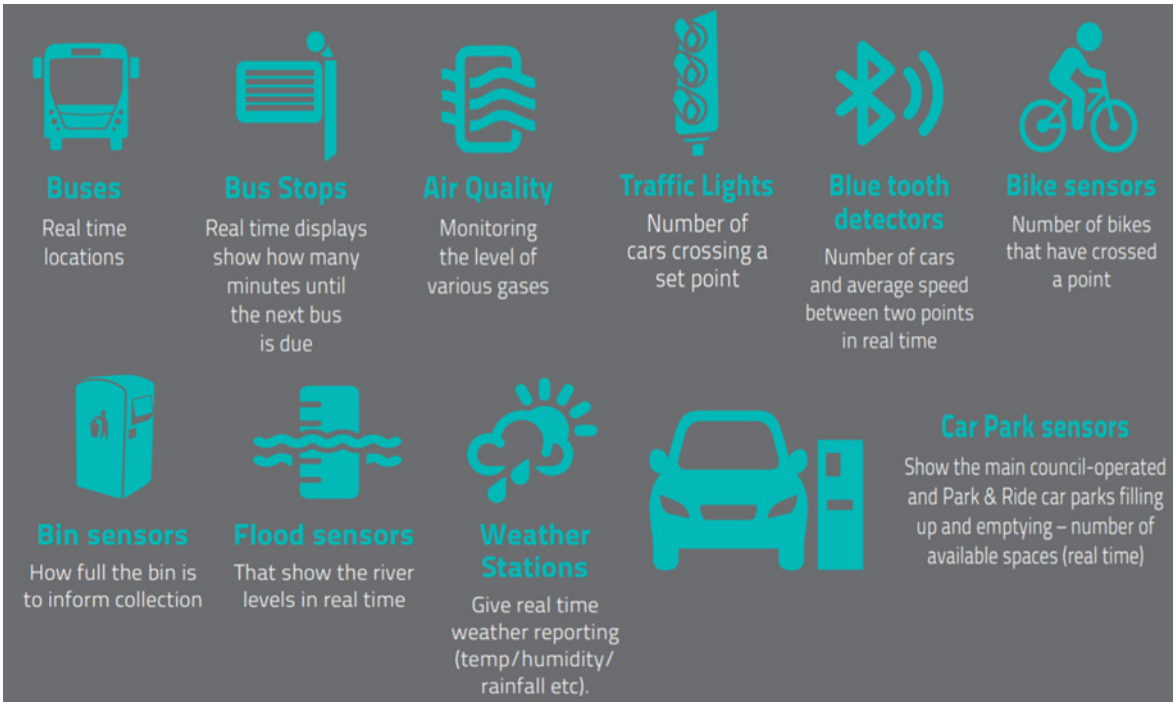
4.1.1 Cambridge, United Kingdom[20]

Best known for the world-famous University of Cambridge, the city of Cambridge, United Kingdom, is a historic town that hosts cutting-edge research and innovation.

The city is one of the leaders in the UK for smart city technology test-bedding and implementation. It has a dedicated organization for these endeavours, Smart Cambridge, which has worked with the University of Cambridge to launch a smart digital platform. Referred to as the Intelligent City Platform (iCP), it collects and processes data from sensors around the city in real time that can be used for a variety of purposes.

Figure 7 shows the diverse areas of sensor deployment in the city.

Figure 7: Sensor deployment in Cambridge[21]

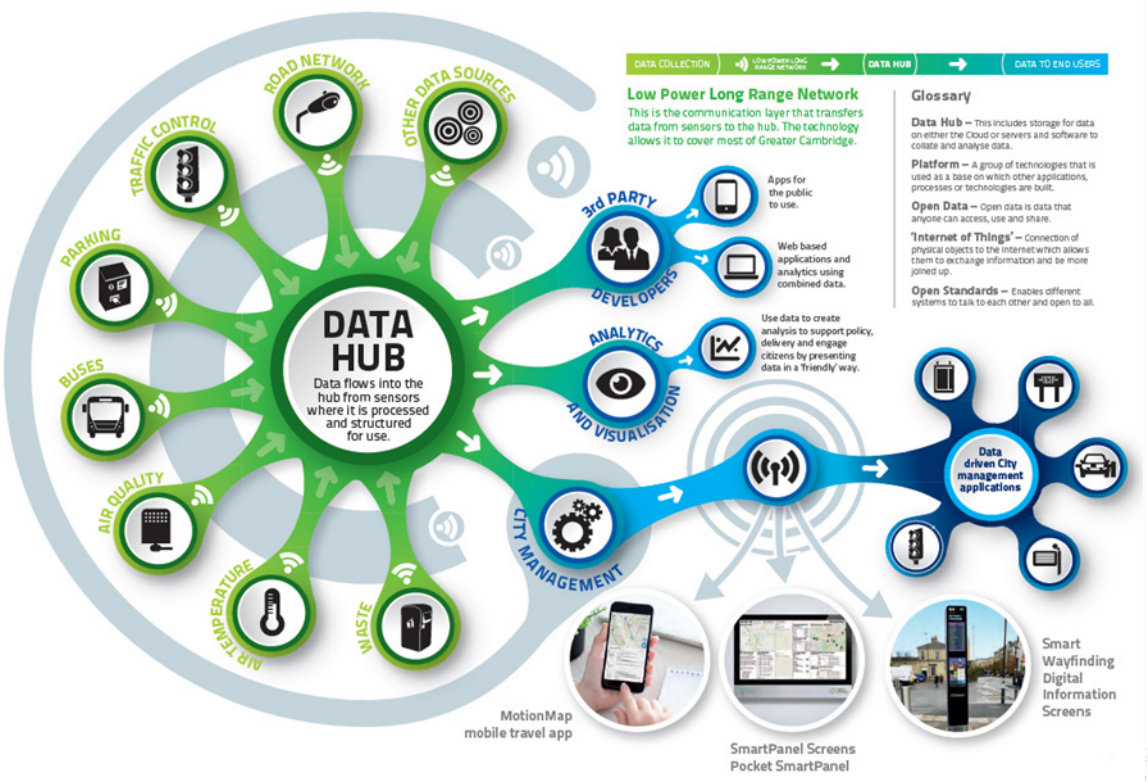


iCP was launched in 2017 by setting up a data network to support IoT connectivity, along with a data hub to collect and process the data. The vast amount of data collected is used to monitor a variety of measures in the city and is analysed and visualized to plan smart solutions, such as the further deployment of tools including SmartPanel screens and the new Pocket SmartPanel app, which provide travellers real-time travel and city information.

Since then, low-power, long-range networks, such as LoraWAN and Sigfox have been deployed to facilitate faster and more reliable data flow from the sensors.

Figure 8 illustrates the key concepts behind the working of the iCP.

Figure 8: Cambridge's Intelligent City Platform (iCP)[22]



A truly collaborative effort involving the Cambridgeshire County Council, Cambridge City Council, South Cambridgeshire District Council, University of Cambridge and private partners, the iCP "also allows citizens, third-party developers and commercial partners to use the data to design and build innovative applications, following examples, such as the MotionMap travel app, Digital Wayfinding Screens and SmartPanels".

Sharing of open data is a key feature of the iCP. It is being combined with data collected by other projects, such as the *Urban Data Project,* to create digital twins and to further study issues around data transparency and protection[23].

4.1.2 El Hierro, Spain

El Hierro is the southernmost and westernmost island of the Canary Islands and Spain. It has three municipalities: Valverde, La Frontera and El Pinar.

The island's smart city initiative is called "El Hierro en Red". It features the implementation of a smart management platform and ICT and IoT solutions in different areas: Sustainability (mobility, waste management and tourism/economy), Smart government (open data, portals and apps with citizen services) and Security and Emergencies (prevention of natural disasters and emergencies in general).

The smart platform acts as the integrating nucleus of El Hierro as a smart city, allowing for the integrated management of the information generated and consumed by different services, thus providing greater control over municipal processes and decision-making. The platform is based on the UNE 178104: 2017 standard, following open, non-proprietary standards and standardized by international organizations and consortia.

It incorporates a dashboard that facilitates the operation of city indicators (KPIs), coming from the different services and systems, for both operational and strategic analysis and for monitoring them.

The smart platform is based on three fundamental pillars:

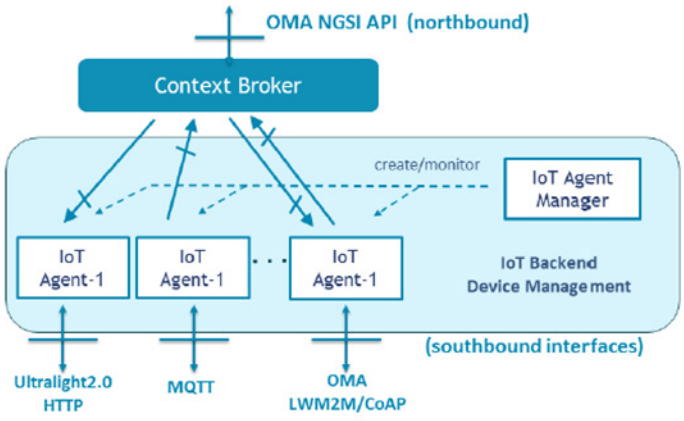
- A smart IoT FIWARE-based platform.
- A Big Data solution for processing data sets through computer clusters.
- A Business Intelligence tool for generating the scorecard, indicators and reports.

The platform allows for the exchange of data with other consumer entities, for example, information and data from volcanological stations which is sent to the systems of entities in charge of analysing and exploiting this data.

- An Open Data Portal has also been developed in which the information available on the platform about the different components is uploaded.
- IoT agents are in charge of receiving data from the devices/sensors and adapting it from the capture protocols to the consumption format used.

Figure 9 shows the system context for these IoT agents, sensor protocols and *Context Broker*.

Figure 9: El Hierro's Smart City Platform – IoT agents and Context Broker[24]



One of the key success factors identified for the smart platform project is the commitment and involvement of leaders from all spheres in the territory, including economic, social and political.

A barrier identified is difficulties encountered in execution in a remote territory (due to double insularity). Project execution costs, logistics and execution times are considered part of this.

4.1.3 Gjøvik, Norway

Gjøvik is a modern small city in Norway that has participated in the U4SSC's SSC-KPI pilot.

Well-known for its technological and industrial presence, Gjøvik is also a centre of higher education, having the highest number of students between Oslo and Trondheim. In addition, it is a centre for culture and music in inland Norway[25].

Gjøvik's strategic approach is informed by national level strategies, policies and initiatives, including:

- National ICT/digitalization strategy for municipalities (from Norwegian Association of Local and Regional Authorities (KS))
- National roadmap for smart and sustainable cities (from Design and Architecture Norway (DOGA))

Gjøvik builds on these through local goals and implementation plans for technological transformation under the auspices of the city council.

The city has an explicit goal of involving local stakeholders, such as citizens, academia and enterprises in its smart city activities. These can range from helping the city map the needs of the local community to helping to develop, test or implement new technologies.

All of Gjøvik's smart city projects are required to deliver results and effects on one or more of these dimensions:

- Environment and climate.
- Social inclusion.
- Economy (for the municipal organization).
- Economy (for the general society).
- Broad demographic and geographic impact.

Gjøvik also frequently collaborates, and shares with and learns from other cities, especially Norwegian cities as part of "Smartbyene", a collective of Norwegian municipalities.

While Gjøvik does not have a city platform for integrated management in place, like the city of Pully in Switzerland (See 4.1.6), it provides an interesting case within this context due to its future feasibility for such a deployment. Two of the factors listed as being behind the decision to not implement a smart city platform include:

1. The "immaturity" of the technology.

2. The ability to employ a "wait and see" approach while establishing a small capability for testing and piloting purposes only. Interoperability is not considered to be a concern or priority at present, and the focus is on expanding the technical platforms within existing silos/divisions for increased automation, quality and effectivity.

Another limiting factor the city has mentioned is its "quadruple helix" stakeholder environment, where R&D work for the stakeholders moves at different speeds. Universities can be slower in pace, while businesses and cities can be both fast and slow, depending on circumstances. Citizens can add further variability. Therefore, getting all the stakeholders' interests, finances and resources aligned for the co-creation of large projects, such as a city platform, take a lot of planning.

Furthermore, 98 per cent of Gjøvik's focus is on operations and only 2 per cent on innovation and R&D. This limits the number of smart city projects the city can run simultaneously.

Other limiting factors include procurement considerations such as legislation often hindering smart city projects, and Gjøvik's preference to buy off-the-shelf products instead of tailor-made whenever possible.

4.1.4 Lisbon, Portugal[26] [27] [28]

Lisbon, Portugal is a modern and cosmopolitan city in Europe that is known for its rich culture and heritage.

Also known for its smart initiatives, the city has implemented a smart city infrastructure platform that has enabled the integration of many data sources, including sensors, internal and external systems, and social media networks using AI and IoT technologies.

The platform collects, stores and analyses data from all over the city and uses it for urban governance, improving citizens' lives, and identifying innovative solutions for urban issues. The *Cloud city operating centre* integrates Lisbon's smart city components into a functional dashboard. The *municipal service operation centre* then uses it to oversee the entire city.

Known as the *smart management platform*, Lisbon's platform solution utilizes open standards such as FIWARE open-source building blocks. The framework includes four key initiatives:

- The *operational integrated centre*.
- The *open data gate – Open Lisbon*.
- *Smart cities projects*.
- The *urban data lab of Lisbon*.

The challenges that led to the implementation of this platform included the need to:

- Improve the services the city delivers to local residents while reducing costs.

- Minimize wastage, increase the timeliness of communications with local residents and free up staff to focus on longer-term strategic planning.
- Manage traffic congestion, parking and public transport availability, street lighting and pollution levels, refuse collection services and park irrigation systems as well as temperature, pollen count, noise, carbon monoxide and ambient light levels[29].

The resulting platform has enabled the following high-level outcomes for the city:

- An integrated operating system that enables Big Data analytics and provides open-source data exchange between agencies.
- Provision of real-time information to the right people enhances informed decision-making.
- The ability to track how water, waste, lighting, power, roads and other resources are used in response to real-time environmental conditions.
- Improved journey planning and alternatives to car transportation[30].

The *urban data lab* project shares the data and information from the platform with the academic community and businesses as a way of collaboratively researching and finding solutions to improve urban planning and urban management. The engagement of start-ups is of particular interest to the project to leverage their innovativeness and expertise to enhancing city resilience.

Topics of research include analysis of local accommodation, optimization of urban waste collection routes, and the prevention and detection of emergency situations in city buildings. Mobility issues and solutions, including e-bike availability, expansion of bicycle networks and design of new routes are also covered. Conventional mobility is analysed as well by identifying patterns and causes of traffic congestion.

The status of conservation of historic buildings is also of high interest, with data on building standards, building history, building age, etc. widely collected, analysed and used to gauge the risk level.

Data to operationalize in the wake of crisis and emergencies, on human and environmental sustainability in the wake of massive tourism flows, on studying local alternative energy sources and measuring how much energy they produce, etc. are also routinely used.

4.1.5 Logroño, Spain

Logroño is a geographically well-connected historic, yet modern city located in the north of Spain. It is famous for, among other things, the Camino de Santiago, and it is a hidden gem of gastronomic excellence.

In 2014, the City Council of Logroño committed to extensive use of ICTs in municipal management, continuing different existing projects and initiatives, completing and expanding the deployment

plan in the infrastructure and communications network, and providing an integrated management platform as an instrument for streamlining government decisions and actions that allows the effective provision of efficient and sustainable municipal services.

The "Smart Logroño" project emerged as a result in the form of a set of strategies, projects and actions that promote a change in the model of governance of the city to turn Logroño into a smart city. The model is based on comprehensive management of municipal services that allows providing integrated and simultaneous solutions.

The governance model focuses on the citizen as the ultimate objective and driving force for this transformation and aims to improve their quality of life, improve their relations with the administration, make more efficient use of available resources and create new economic activities that promote job creation and entrepreneurship.

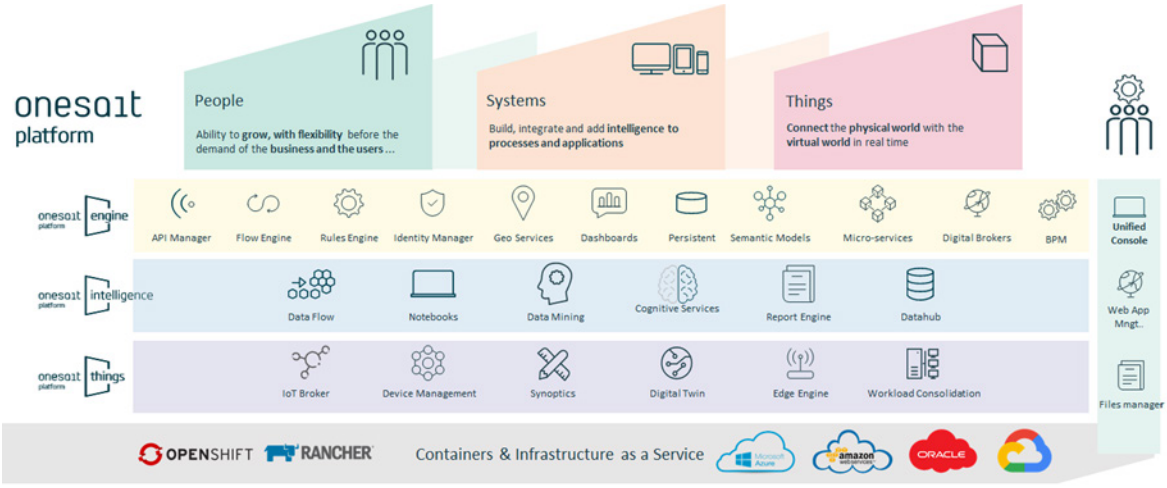
Developed in line with strategic ICT plans at the national level (such as the Spanish Strategy of Science and Technology and Innovation and the National Plan of Smart Cities of the Digital Agenda for Spain), at the local level (such as the Strategic Plan of La Rioja 2020 and the Digital Agenda Rioja), and at the municipal level (with the *Municipal Plan* for the implementation of the Electronic Administration and the Master plan for the integration of Vertical Services), the Smart Logroño Platform includes:

- Installation of information and communication technology infrastructure to complete the deployment strategy to serve the Smart Logroño Platform and Integral Control Centre (ICC).
- Post-commissioning and maintenance of the *Comprehensive City Management Platform* including:
  - A platform core with basic and cross-cutting modules for municipal intelligence: data capture and standardization, device management, analytical and geo-referenced data management, mapping, reporting, indicators and executive dashboards for service management and global views for city governance, active interrogation and listening on social media and availability of APIs for integration and interoperability with systems.
  - Additional common functionalities and applications to vertical services to integrate and facilitate communication and relationships with citizens from the services of the Integral Control Centre, including management systems for warnings and incidents, alerts and road conditions.
  - Smart city portal for citizen access to contents of the Smart Logroño Platform and an Open Data Portal.
- Support for daily operations, attention to incidents, and the evolution of the integral management platform of the city, including the consulting, development and implementation of projects incorporating contents of municipal systems and collaboration and participation in vertical service integration projects.

The Smart Logroño platform provides the flexibility for developers to build their own solutions in a robust and agile way using open-source technologies, flexible architecture and an innovative approach. It has the entire information lifecycle, from initialization to visualization. The platform provides a unified web console for solution development and operation profiles.

The platform is deployed in two environments, with four nodes, each containing different modules. The modules are contained such that they can be managed individually and can continue the functionality of the platform even if a module is failing. Figure 10 highlights the platform components.

Figure 10: Smart Logroño Platform components (Logroño City Council, internal elaboration)



4.1.6 Pully, Switzerland

Situated in the Canton of Vaud close to Geneva, Pully is Switzerland's first city to participate in the U4SSC SSC-KPIs pilot programme.

Pully's smart city approach is highly strategic, whereby the city invests in and uses new technology solely to improve the lives of its citizens and the work of its civil service employees. Each potential project in the city is evaluated according to the following four characteristics-based criteria:

- Human
- Efficient
- Friendly
- Practical

This approach has thus far resulted in investment in technologies needed for approved smart projects, rather than an overarching smart city platform. Each smart project is implemented as described on Pully's website[31].

Pully's approach is useful to illustrate as it is a sound start towards eventual implementation of a smart city platform. Certain projects that have been successfully launched have provided components that could be rolled into a future city-wide platform. An example is the digital mobility observatory project that saw Pully partner with Swisscom, a Swiss telecommunications operator, on a Big Data project. Using visualization of the traces left by mobile phones on Swisscom antennas, the project quantified and measured the attractiveness of Pully's city centre to:

- Determine where Pully should improve in terms of its infrastructures, such as roads, bus lines, and public squares.
- Acquire the basic information for the sizing of the future infrastructure.
- Measure the return on investment (ROI) after the construction of new infrastructures.

Other projects that have been developed in the fields of cyber-administration and open-source software to manage public infrastructures, digitalization in the social service sector, etc. could also contribute to or be integrated with a smart city platform in the future (see Figure 11).

Figure 11: Pully's smart project online repository snapshot[32]

4.1.7 Trento, Italy

Trento is a financial, political, educational and scientific centre in Northern Italy. A generally wealthy and prosperous city[33], it ranks highly in measures of quality of life, the standard of living, and economic opportunities.

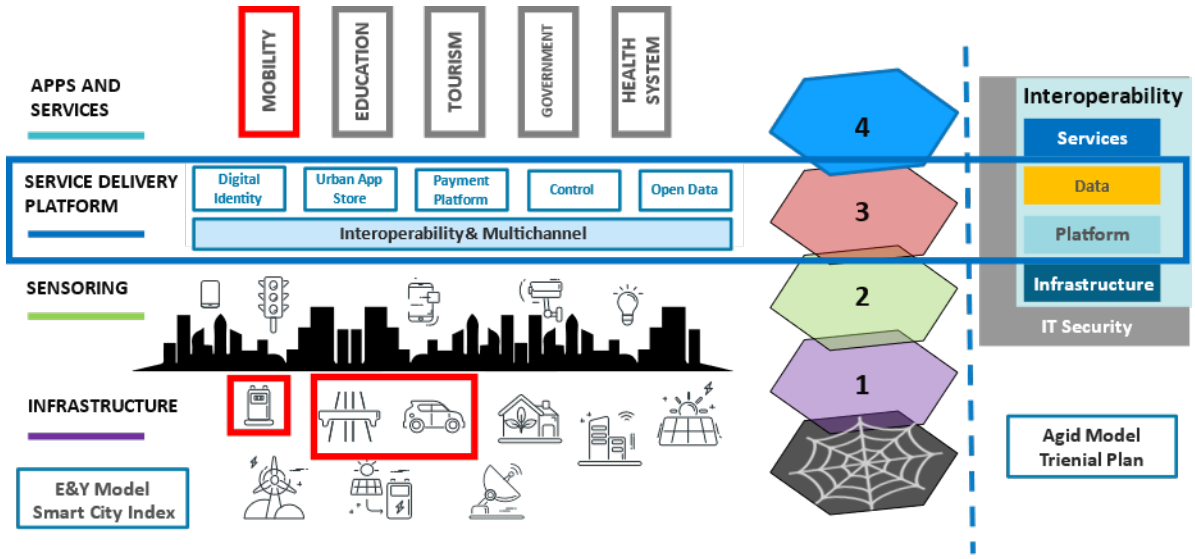
The city's smart city strategic vision and purpose centres around using technology as a means to innovate and improve the services it offers to citizens and businesses and the quality of life in general. This includes increasing the well-being and sustainability of the city while preserving its history and culture.

The city plans to achieve this through participatory processes that involve citizens, businesses, institutions and all the other local stakeholders that wish to actively contribute. An important objective mentioned in Trento's Digital Agenda of 2020 is that of reinforcing cooperation and

synergy among all stakeholders (private and public) that operate in the city's ICT ecosystem. The city hopes to instil a culture of data sharing, enabling technological platforms and other interoperable systems that make it possible to focus on cross-sectoral and multi-level scenarios while simplifying municipal processes.

To this end, a new smart city operating system is currently being implemented in Trento in collaboration with institutional and technological partners. The operating system consists of four horizontal layers (infrastructure, sensors, service delivery platform, applications and services), as seen in the following Figure 12.

Figure 12: The architectural layers of Trento's smart city system



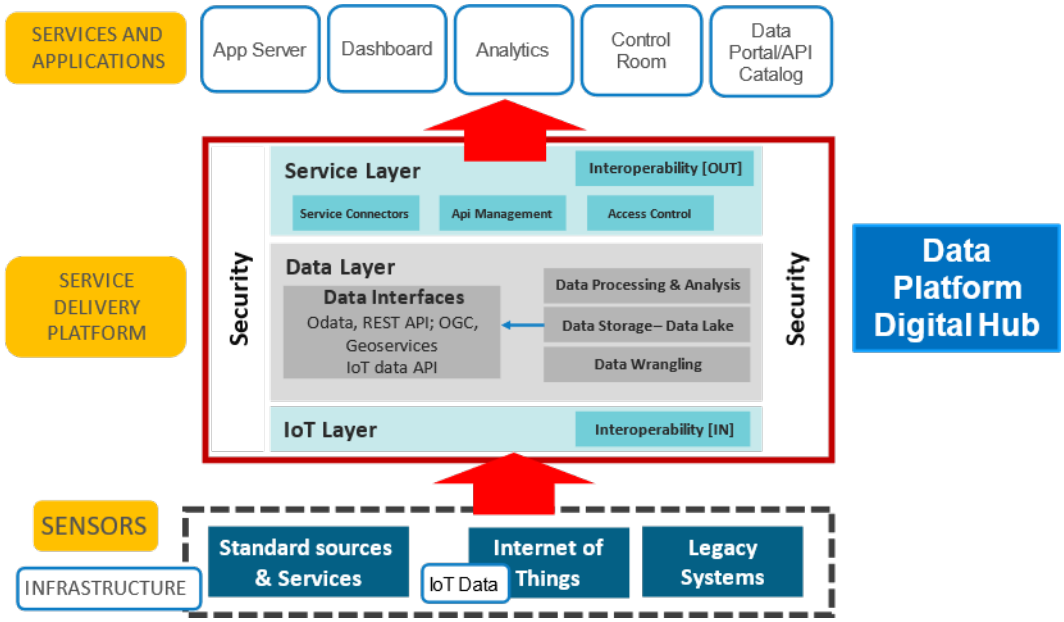
The core of the smart city system is represented by the "Digital Hub", the service delivery platform that allows it to import and organically manage both static and near-real-time data that comes from existing infrastructure. To do so, the Digital Hub exploits an interoperability interface that links legacy systems, different IoT sensors and all the sources and services that can be accessed via standard APIs.

By exploiting the single components of the *Digital Hub*, it is possible to organically manage, collect and classify all the data using common ontologies based on international standards while working on improving the quality of the data at the origin and transforming these data into useful information, thereby enhancing the value of public information assets. All this is propaedeutic to link and integrate data referring to different areas which are to be seen as different sides of the same coin.

This approach also allows the transformation of this information into knowledge while building value-added applications and services upon the data as well as evolved analytics systems that could support the decision-making process, and last but not least, a veritable "smart city control

room". Furthermore, it is of vital importance to make such data available in an open modality, either as open data or through standard APIs, possibly in an unrestricted manner. If this is not possible, it could at least be provided to companies or other public administrations in protected mode. Figure 13 illustrates these concepts.

Figure 13: An illustration of Trento's digital hub data platform



Future plans in Trento include leveraging the infrastructure that is currently being implemented along with other smart projects (which are in progress) as a way to combine technological and environmental sustainability in fields such as mobility and electricity production.

4.1.8 Rivas Vaciamadrid, Spain

Rivas Vaciamadrid is a town located less than 15 km from Madrid (Spain) and with a population of approximately 92,000 inhabitants, it has become the largest demographic progression of a European city in recent decades.

In 2004, it began its digital transformation project with the deployment of a technological infrastructure based on optical fibre. Its smart city model and its environmental policies are reflected in the "Rivas Zero Emissions Plan". In addition to the implementation and development of the "Rivas 2030 Strategy", the use of ICTs to improve the effectiveness and efficiency in the management of public services are contemplated in "Rivas 21.20 Digital: the Digital Agenda for Rivas Vaciamadrid". These guidance instruments contain projections of what the city can achieve as an innovative promoter of a sustainable socio-economic model. Also aligned with this strategy, "RivaSmart" belongs to the RECI group, the Spanish Network of Smart Cities, and has participated

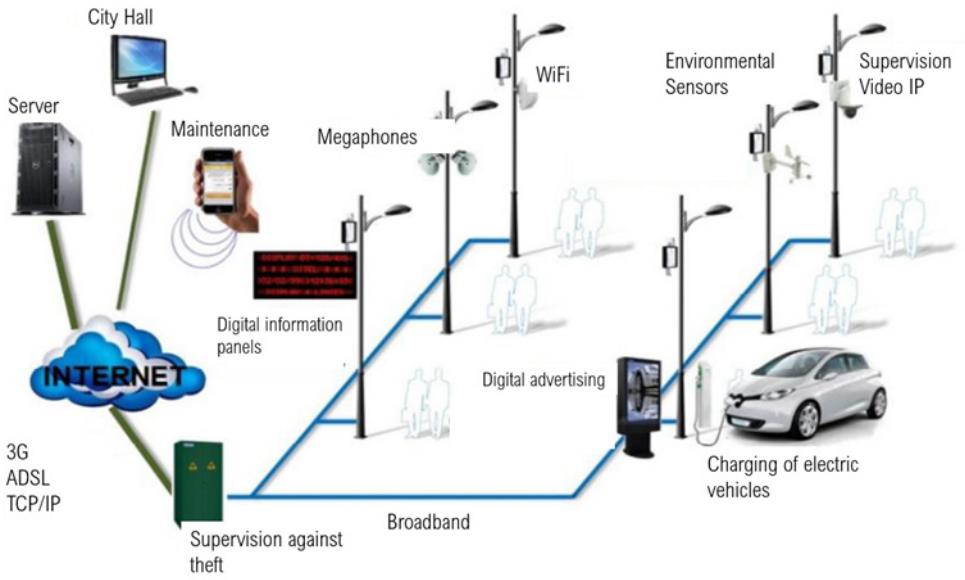
in the AENOR/UNE CTN 178 "Smart Cities" Standardization Committee as head of the Infrastructure Subcommittee.

The platform has allowed the transformation of services from a comprehensive point of view and the application of open data policies as well as greater transparency in the management of public services. The platform is based on the Spanish model UNE 178104: 2017 and is mainly made up of components subject to open-source licensing. Additionally, the city semantics follow the FIWARE model. The platform allows integration of diverse data sources with multiple structures through a Big Data approach.

Some of the most outstanding technological solutions deployed are:

- Multiservice IP network infrastructure (based on fibre optics) that converges with other infrastructures, such as PLC, IoT NarrowBand and Wifi4EU.
- Deployment of intelligent lighting and irrigation sensors, fixed and mobile air quality stations (meteorological sensors as well as air quality and noise monitoring sensors), twenty-one electric vehicle charging points, etc. They contribute to reducing consumption and CO2 emissions as well as the increased use of LED luminaires.
- An IP video surveillance network that, together with the video analytics and the license plate reading system, allow for improving the security in the city, controlling mobility, managing traffic, detecting jams or accidents, etc. This system interacts with the lighting system to reduce consumption or increase it in emergency situations.

Figure 14: Smart Broadband PLC Network, Smart Lighting and Irrigation



- Wi-Fi network deployed in 100 per cent of public buildings with a total of 630 4x4 MIMO indoor APs and 130 outdoor APs.
- SCADA system for buildings and elements of public roads. It manages more than 8,000 control points (sensors and valves) that emit information regarding the temperature, water systems, electricity, fire alerts and energy management of municipal buildings. Likewise, the city council has an Energy Manager that monitors the operation of buildings, generates KPIs with alerts and incidents, detects opportunities for optimizing the operation of buildings, saves energy and extends the useful life of the equipment.
- IoT NarrowBand sensor network for:
  - Location bracelets for the care of the elderly with cognitive impairment.
  - Control and location of municipal assets (fences, cleaning trolleys, etc)
  - Monitoring of parking spaces and loading and unloading zones.

In addition, the city platform has facilitated the creation of a *Unified and Economic Management Panel* as well as a *Transparency and Open Data Portal*. Finally, there is a city App and a new municipal website that integrate all the information in a single environment and foster the completion of administrative procedures.

In 2020, the *Innovation and Modern department* was created to promote and evaluate the execution of the "RivaSmart" initiative, gather know-how, and study possible additional financing models (public-private collaboration, aid or subsidies at the European level, etc.). In addition, there is a management and control entity, where the different departments of the city council are involved. Finally, the department is made up of a multidisciplinary team and specific smart clauses have been included in the technical specifications.

The main sources of financing are grants and municipal investment that have an impact on investment returns from direct savings in supplies (electricity, gas, water, etc.), optimization of processes, and value-added services to improve the quality of life of citizens. There is currently no monetization strategy for the information contained on the platform.

Connectivity is a key element to boost broadband and reduce the digital gap. In addition, it is essential to convince political leaders, have a solid organizational structure, involve the entire organization and provide adequate financial resources.

4.1.9 València, Spain[34]

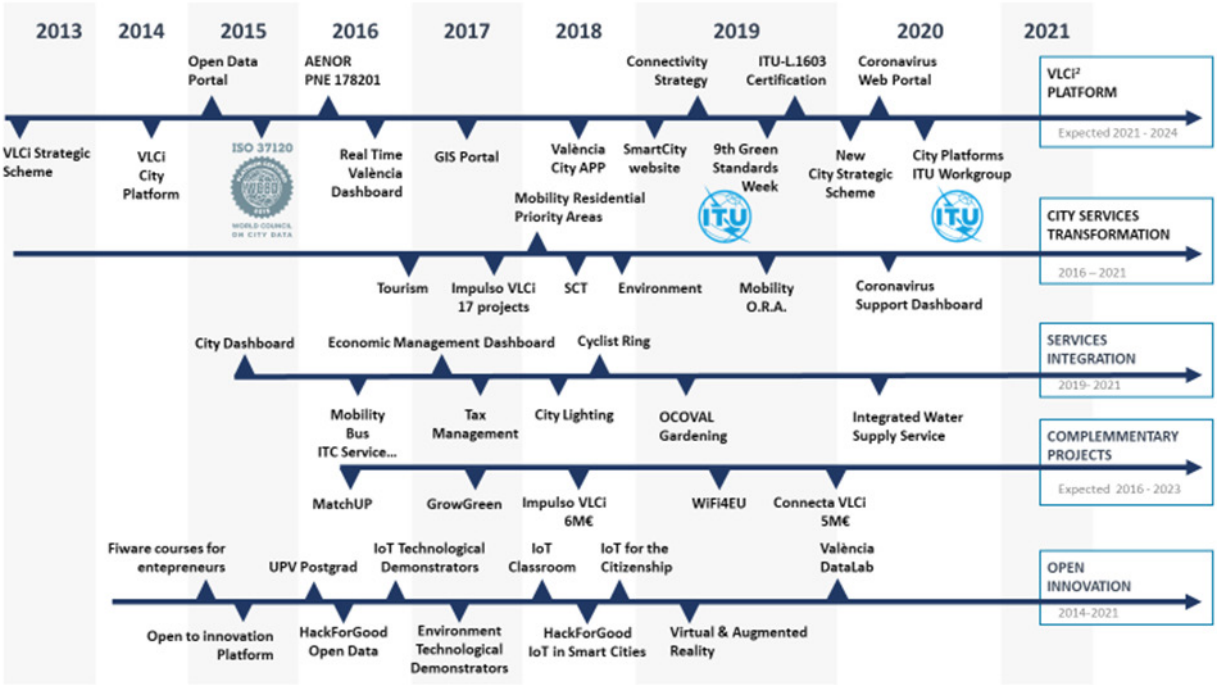
València has been participating in the U4SSC initiative's KPI pilot programme to monitor their journey towards becoming a leading smart and sustainable city.

València started its smart city journey in 2014 and was one of the first cities in Europe to successfully implement a smart city platform based on open and interoperable standards. The VLCi Smart city

platform is an important milestone on the city's roadmap towards integrated management, and eventually as an open hub for the transformation of municipal services which would include the city's entrepreneurial and research sector.

Figure 15 summarizes the main milestones aligned with sustainability, smart management and compliance with the València 2030 Missions[35]. Descriptive information of the most relevant results of the project is available on the València smart city web page[36].

Figure 15: València Smart City Milestones[37]



València currently uses a cloud platform based in the open source FIWARE standard, the CEF (Connecting Europe Facility) message exchange broker standard of the European Commission, and the UNE 178104 standard. The platform has three environments (production, pre-production and development) and an additional environment for geographic redundancy, located in two different data centres.

The platform's components are comprised of the following:

- IoT agents for receiving data.
- IoT device management portal.
- Interconnection broker.
- Platform administration portal.
- NGSI data adapter.
- Small data storage module.
- CKAN open content.
- Transparency and open data portal.
- Big Data system.
- Analytical databases.
- Microstrategy BI environment.
- Data visualization and analysis tools.

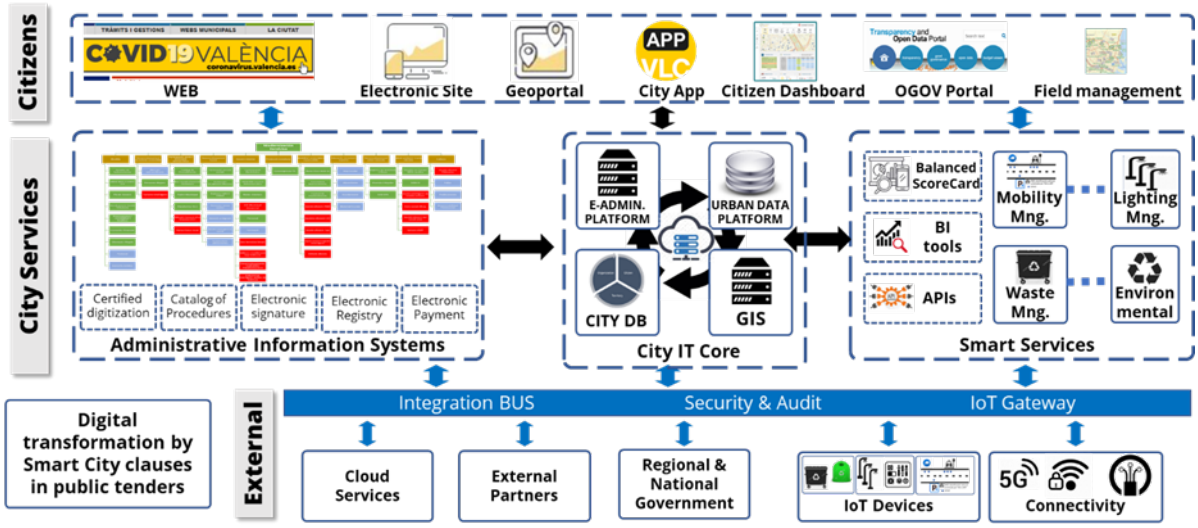
The platform also has several servers for the execution of data acquisition and integration tools with external systems (ETLs). It is secured through user authentication, systems monitoring and auditing. It offers several integration interfaces for sensors and devices data acquisition, and for access to information on the platform. Figure 16 shows a high-level description of IT components and their relationship with smart city challenges.

València is deploying a large number of sensors and actuators to monitor the environment, meteorology, noise, luminaires and copper theft, presence detectors and capacity control, cameras, waste, parking, electric vehicle charging stations, energy, water, gas consumption and building management systems (BMS), etc.

The *València unified dashboard* integrates all kinds of resources from the platform, data from municipal services, data from devices deployed in the city, social media data, etc., including georeferenced data and data that comes from the city's open data portal[38]. It links with individual dashboards or scorecards for economic management and budgetary control, mobility and traffic, open data services and the municipal geographic information system services, etc.

On the citizen side, the platform links with AppValència[39] that integrates into a single space geolocated information (map) of bus and metro stops, municipal bicycle service, notifications in real time with traffic alerts, emergencies, as well as a section on Tourism and culture with routes, historical monuments, etc.

Figure 16: València IT challenges, Smart City Framework



The Impulso VLCi project[40] will see the city adoption for new solutions in five different smart areas: mobility, governance, environment, society and well-being. This includes 17 initiatives, some of which are already operational, such as real-time monitoring of the occupancy of parking spaces with reduced mobility (PRM), loading and unloading taxis, monitoring in real-time the filling of containers, intelligent management of public lighting, deployment of environmental stations in the EMT (Municipal Transport Company) bus fleet, deployment of noise sensors in problem areas, fast-charging stations for electric vehicles with their respective occupancy sensors, regulated parking management, among others. These initiatives will introduce new services for citizens and will enrich the VLCi platform with new indicators and useful information for city decision-making.

The "Connecta VLCi" project, currently in technical specification phase, includes the deployment of sensors and actuators to monitor and control 194 municipal buildings, and the development of new services for citizens, such as:

- A dynamic guidance system for municipal museums.
- A platform for environmental awareness for the educational community.
- An App for the reservation of sports facilities.

It also considers the connection of the city platform with systems of other public-private entities (ADIF, AENA etc) that allow the exchange of information of mutual interest.

The Valencia city council, to continue with its corporate strategy of digital transformation, established the *Smart City Office* on 16 February 2018 under the Delegation of Digital Agenda and Electronic Administration of the City Council.

4.2 ASIA AND PACIFIC, MIDDLE EAST AND AFRICA

4.2.1 Abu Dhabi, United Arab Emirates[41]

Abu Dhabi is the capital city of the United Arab Emirates (UAE), and has a leading role to play in the digital transformation of the country.

The *Abu Dhabi City Municipality* invested in a five-year smart city initiative called the *Zayed Smart City* project, which involves managing infrastructure through the use of emerging technologies. Commencing in 2018, the pilot phase validated key use cases and the project's viability to digitally transform the economic, environmental and social aspects of life for Abu Dhabi's citizens and businesses.

Significant investment was made in IoT infrastructure and network technologies, including sensors, actuators, and management systems to connect key components across the city. The project used low-power WAN (LPWAN) technologies to capture sensor data from across the city and feed it into an integrated system to monitor and manage the use-cases.

The ten use-cases included "air quality monitoring, asset tracking and logistics monitoring, structural health monitoring, water metering, palm tree weevil detection, street lighting, smart parking, waste management, water storage tank monitoring, and swimming pool monitoring"[42].

Abu Dhabi's implemented IoT solution is designed to ensure secure, quick and easy connectivity to any 'thing'. It can operate across the cloud, on-premises and at the edge.

The *Zayed Smart City project* is currently ongoing, with more information on its achievements and lessons learned to likely become available in the next few years. While the pilot project was implemented in Abu Dhabi's 'Corniche Area', smart services resulting from the project will likely expand through IoT and AI platforms to other parts of the city by 2022[43].

4.2.2 Auric City, Aurangabad, India[44] [45]

Aurangabad is home to India's first greenfield industrial smart city, Auric City. The mega-investment project is part of the state of Maharashtra's upcoming Delhi-Mumbai Industrial Corridor. Within close proximity to the Aurangabad International Airport, the Jawaharlal Nehru Port Trust's dry port and the container terminal at Jalna, Auric City is set to be a major exports and logistics hub in India.

Part of India's 100 Smart Cities initiative, Auric City is deploying state-of-the-art IoT-enabled technologies that use real-time data to make life in a city smarter, safer and more sustainable.

The start of the project has seen the deployment of an optical fibre cable network that covers 8.45 km^2 to support the installation of closed-circuit television (CCTV) cameras, Wi-Fi access points and a centralized state-of-the-art command and control system (Smart City Platform) that will integrate

various functions of city management, including power, water, security, telecommunications and other utilities[46]. The platform will also integrate or support a traffic management system, environmental sensors, solar panels, multi-service digital kiosks and a solid waste management system[47].

The platform will allow for the management of city operations from Auric Hall, which will house the *Auric Command and Control Centre* (ACC) – the point of integration for all city infrastructure and systems. GIS-based visualizations will be a key feature of the smart city platform, allowing for real-time monitoring and control.

Figure 17 shows the integrated bird's eye view of various city operations on a video wall at the centre.

Figure 17: Auric Command and Control Centre (ACC)[48]

The ACC runs on collaborative, cross-departmental decision-making. The smart city platform is, therefore, vital to its efforts to analyse, optimize and manage city operations based on this collaborative philosophy. The platform's functionality includes threat detection, emergency and event alerts along with real-time location monitoring of emergency vehicles, such as ambulances, police vehicles and fire fighting vehicles to ensure a timely response. It will allow for advanced operations, such as integrated monitoring of control of SCADA systems for water and power, and geo-tagged monitoring of grievances and complaints filed by users, to be carried out seamlessly.

The platform will enhance citizen engagement by providing municipal staff real-time streaming analytics on Twitter, social media posts, blogs and other applications. It will integrate the modes of contacts available to citizens at the ACC, including SMS, email, telephone, mobile application and social media to provide a better service experience to citizens.

4.2.3 Broken Hill, Australia[49]

Broken Hill is Australia's first city to be included in the National Heritage list. With an economy originally rooted in mining[50], its city council is actively investing in opportunities to promote Broken Hill as a liveable city steeped in cultural and tourism experiences. Investment in technology is key to making the city more dynamic, productive and safe for this purpose.

To this end, Broken Hill is implementing an IoT-based city platform that will be supported by a myriad sensor applications to manage all aspects of life and governance in the city. The areas of focus for the city platform are:

- City and community planning.
- Visitor experience.
- Facility and services management (buildings, energy, waste, utilities).
- Public administration and customer service.
- Public safety (crime and disaster prevention and management).

The city platform aligns with Broken Hill's Smart Cities Plan, which will affect a transition of the city's economy beyond mining and will revitalize the central business district (CBD) by creating a smart cultural hub in the CBD and attracting new businesses.

It will act as a key competitive advantage by allowing Broken Hill to become a smart community that relies on smart, integrated technologies to promote synergies and growth across the region[51]. It will lead to more intelligent and evidence-based decision-making, which would be essential during such growth.

The platform design is scalable, enabling Broken Hill to add manageable projects when its budget presents such opportunities to invest. This approach allows for the flexibility needed to align the platform with future changes in community characteristics and priorities.

The various projects that complement Broken Hill's IoT platform:

- Smart bins trial, including an extension to the Council's free Wi-Fi programme.
- Smart parking sensor trial, which will help inform the planning of a new library and cultural hub and potentially reduce on-street traffic congestion by more than 30 per cent.
- Environmental sensors in the city's main event park.
- BBQ sensors on new park development for a reduced cost.
- CCTV for improved public safety and protection of assets, especially to grow the night-time economy.
- CBD smart lighting.

The smart lighting and CCTV projects use solar and wind technology, thereby reducing Broken Hill's overall carbon footprint and improving its future environmental sustainability.

4.2.4 Dubai, United Arab Emirates[52]

Dubai, United Arab Emirates (UAE) was the first city to join the leading-edge on many transformational smart project implementations in the region.

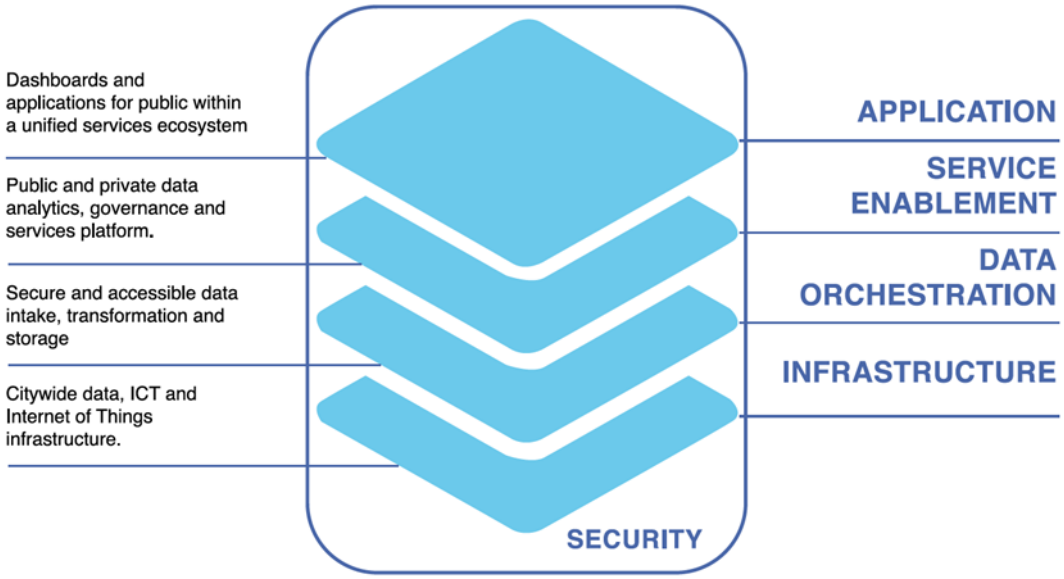
One such project is the *Smart Dubai Platform* (SDP) which integrates data and functionality from various traditionally siloed city systems, thereby connecting "diverse ecosystems ranging from the simplest of sensors through to the most complex government entity systems"[53].

Part of the *Smart Dubai 2021* strategy, the platform consists of five layers:

- Infrastructure.
- Data orchestration.
- Service enablement.
- Application.
- Security, which encompasses all layers.

Figure 18 illustrates these layers and lists brief use-cases for each.

Figure 18: Simplified view of the architectural layers of the Smart Dubai Platform[54]



The SDP provides specific tools to government agencies including[55]:

- Dashboard and analytics tools.
- Digital ID services.
- Digital payment gateway supports monetization of government services and data.
- Platform as a service layer and an application environment that enables government agencies and private partners to develop applications for citizens and companies.
- Geolocation data support for interactive services.
- IoT Management and data aggregation.
- Open city data catalogue.

The SDP model relies on and encourages and leverages collaboration both within the government and with vendors and service providers who become the platform's 'strategic partners'.

SDP successfully leverages public-private partnerships (PPP). This eliminates the necessity for a large upfront capital investment by utilizing collaborative PPP business and financial models. These models provide the added benefits of:

- Value for money.
- Design and operational optimization.
- Shorter delivery times.
- Sharing of financial and operational risk with private companies.

Thus far, the critical success factors identified for the Smart Dubai Platform (SDP) include:

- "Enhancement of transparency, efficiency and seamlessness of Government services.
- The diversity of applications on the SDP for usage by Government entities, the private sector, residents and visitors to the city of Dubai.
- The volume and accuracy of data available to be shared between Government entities and opened to the private sector and the public.
- A reputation for security and flexibility.
- The ability to deliver new, impactful services which were not possible until the platform was available"[56].

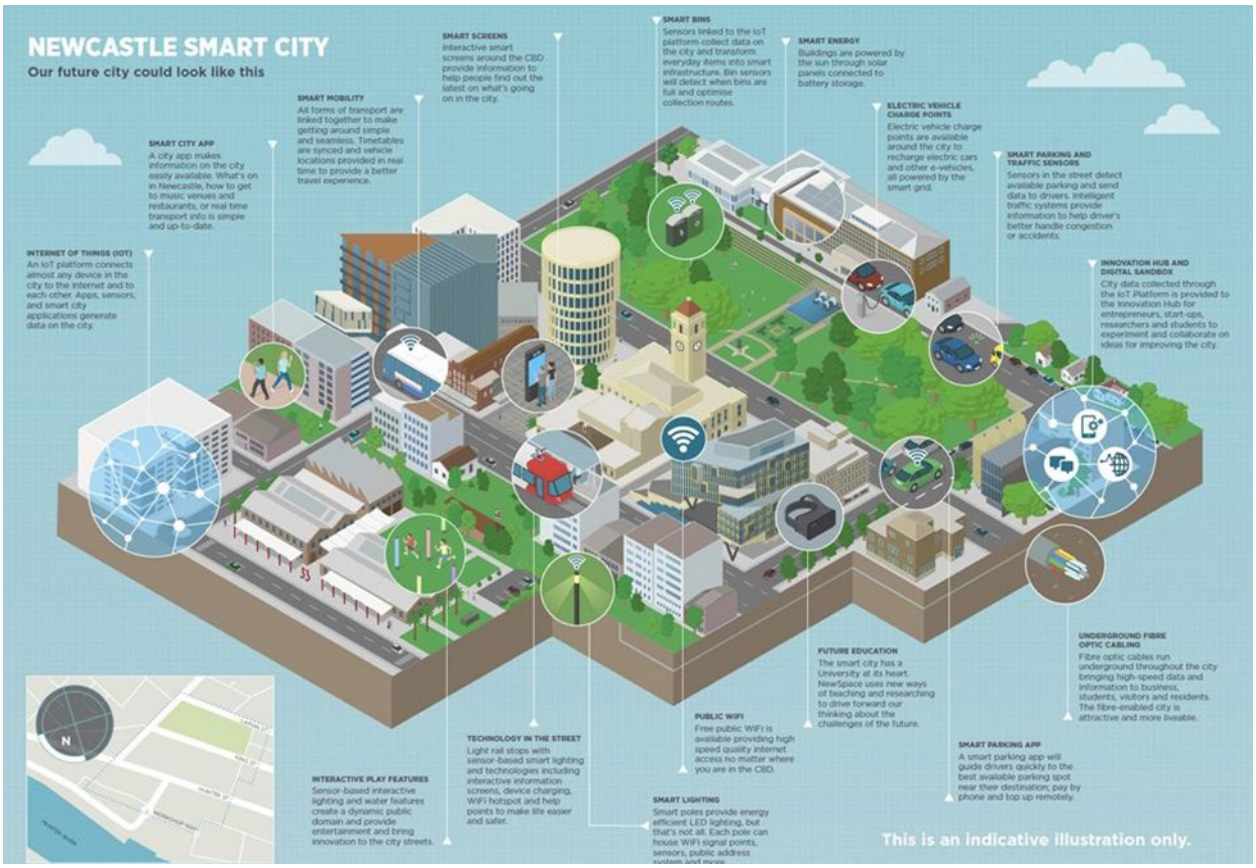
4.2.5 Newcastle, Australia[57]

Located two hours away from Sydney[58], Newcastle, Australia is the hub of the Greater Newcastle area and part of the second most populated metropolitan area in the state of New South Wales.

The city is set to implement a smart city intelligent platform as part of its *Newcastle Smart City Strategy* 2017-2021. The platform is expected to help "maximize opportunities in sectors including technology, advanced manufacturing, the digital economy and the creative industries"[59]. To this end, Newcastle is also sharing information on its smart city platform with other cities in Australia.

Figure 19 illustrates Newcastle's detailed smart city vision.

Figure 19: Newcastle's smart city vision[60]



The intelligent platform will "integrate, consolidate and manage data from a wide range of IoT devices, systems and citywide sources to enhance the productivity of city services, better connect citizens with timely information, and facilitate advanced data analytics"[61]. The platform will eliminate data silos and promote interoperability and integration of data and services for greater efficiency and effective resource management.

For example, the platform will collect and process real-time data from soil moisture sensors in city parks and will combine it with weather forecast data to optimize the management of city water resources in various parklands. Similar outcomes can be achieved using smart parking sensors and smart bins across the city.

Open data sets and visualization capability will be a key feature of the platform and will be accessible to citizens and researchers via easy-to-use web-based tools. This will increase R&D and innovation in the city and will allow the test-bedding of ideas.

Key design consideration for the platform is to decrease the barriers to implementing new capabilities. This necessitates the simplification of the introduction of new services while reducing associated costs.

Another key success criterion for the platform is the "seamless integration with other technologies selected by Newcastle, including Amazon Web Services, NNNCo and OpenDataSoft"[62].

4.2.6 Singapore

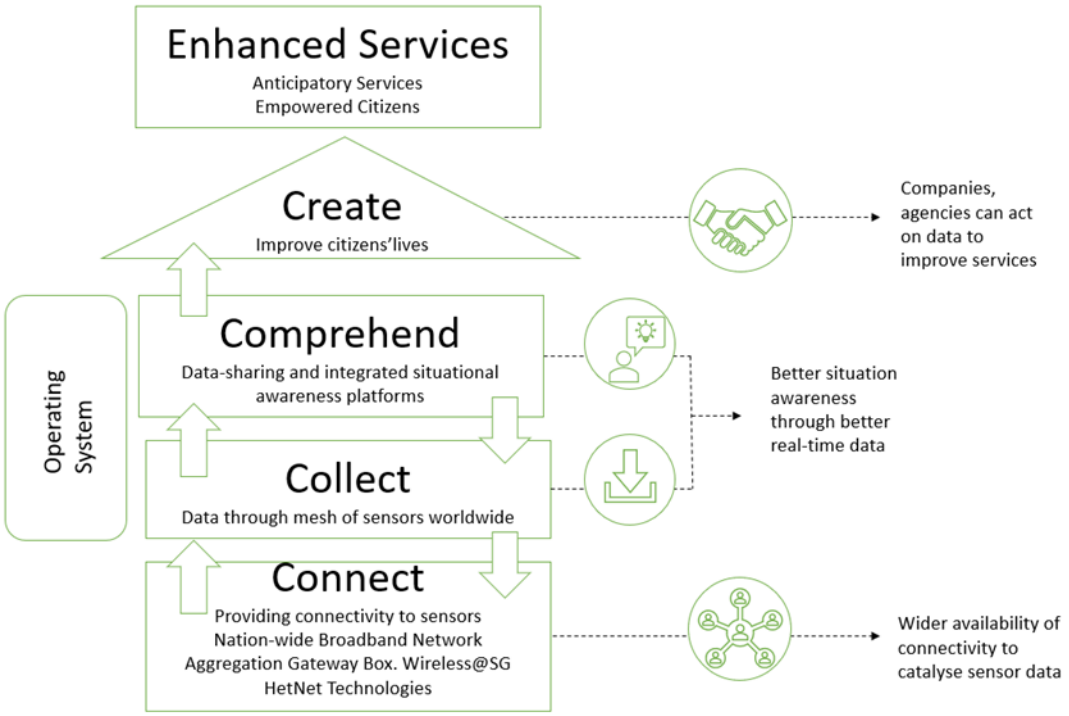
The prosperous city-state of Singapore participated in the U4SSC KPI pilot programme in 2016-2017.

For years, its *Smart Nation* vision has been guiding its continual technological transformation, which aims to serve citizens and businesses better, including through empowering citizens and businesses with information and meaningful data.

Singapore's *Smart Nation Sensor Platform* (SNSP) has been developed by its *Government Technology Agency* (GovTech) with the goal of mainstreaming "common infrastructure and services such as a data sharing gateway as well as video and data analytics capabilities".[63] The effort helps public agencies "optimize their sensor deployment needs, the sharing of data collected and data analytics to support needs like urban planning and incident response"[64]. One of the SNSP's goals is to "help public agencies in the efficient running of the city"[65].

Figure 20 shows the three areas that the SNSP centres around.

Figure 20: Singapore's SNSP's key areas of Connect, Collect and Comprehend[66]



The SNSP infrastructure and common services support smart applications in the areas of:

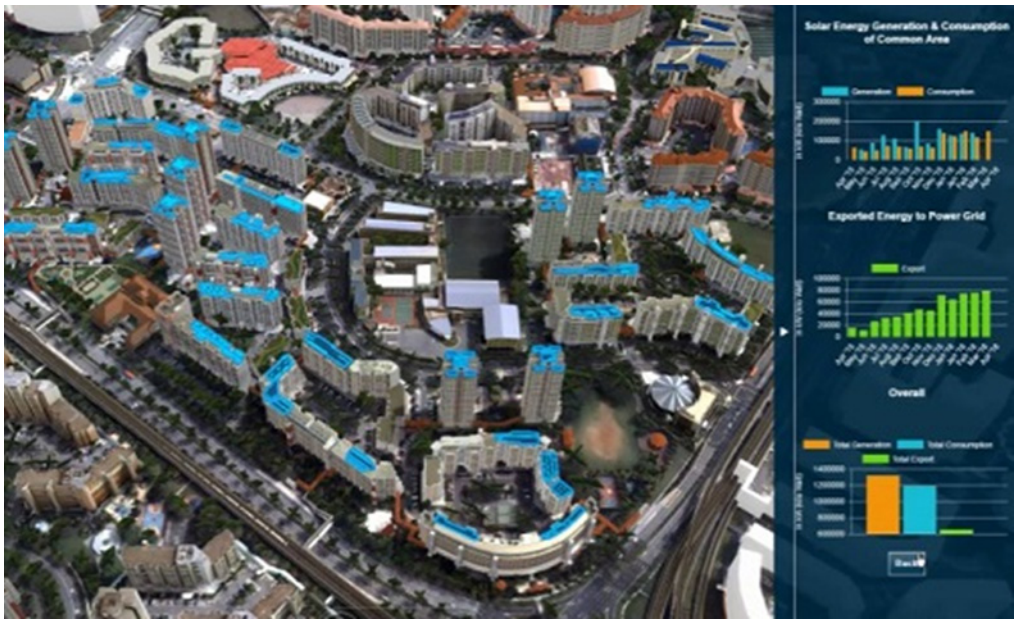
- Mobility.
- Safe and secure city.
- Urban habitat.
- Energy.
- Education.
- Health.
- Lifestyle.

The SNSP allows public agencies to collect, analyse, and share data from sensors deployed all over the island-state[67]. Both public and commercial infrastructure are used to facilitate the SNSP's scalability and connectivity based on the sensor deployment needs of public agencies.

Applications of the SNSP include (or will include) facilitation of smart utility management; providing consumers with timely information on their utility consumption; video analytics for anomaly detection, human traffic patterns and vehicular counting for public transport planning; energy-efficient *light-emitting diodes* (LED) for street lighting with *remote control and monitoring system* (RCMS); lamp-posts with CCTVs, environmental or motion sensors, or navigational beacons to guide autonomous guided vehicles, etc.[68]

In addition to all the technologies mentioned, Singapore has opted for a Digital Twins Platform, called "Virtual Singapore". Virtual Singapore is a dynamic three-dimensional (3D) city model and collaborative data platform, including the 3D maps of Singapore. Virtual Singapore will be the authoritative 3D digital platform intended for use by the public, private, people and research sectors[69]. Figure 21 shows how urban planners can analyse the buildings that have a higher potential for solar energy production and are therefore more suitable for the installation of solar panels.

Figure 21: Screengrab of Virtual Yuhua



It will enable users from different sectors to develop sophisticated tools and applications for:

- Test-bedding concepts and services.
- Planning and decision-making.
- Models that simulate climate change and analyse the potential for solar energy production.
- Infrastructure planning and public health studies.
- Urban planning.
- Improved accessibility.
- Research on technologies to solve emerging and complex challenges.
- Crisis management.

4.2.7 Shanghai

With a population of more than 24 million, Shanghai is the largest metropolis in China. The smart city strategy for the city was initiated in 2010 and has been underway since then. As a part of this strategy, the city intends to facilitate a holistic transformation.

City Brain architecture also forms a part of Shanghai's smart city endeavours. The functioning of this architecture is fundamentally dependent on the following operations: data aggregation and sharing, network infrastructure development, system integration and collaboration, and the openness of the application ecosystem. Additional information on the operations is as follows:

1. *Data governance*. In 2018, the Shanghai Municipal Big Data Centre was established as a cross-level, cross-department, cross-system and cross-service data sharing, coordination and exchange platform for government, industry and social data.
2. *Network infrastructure*. Shanghai has adopted the implementation of new and emerging technologies including the Internet of Things (IoT), artificial intelligence (AI) and blockchain to support integrity of their architectural framework and strengthen security of the overall systems to external threats. It has also facilitated full 5G coverage in the downtown area.
3. *System integration and collaboration*. Unifying portal integration, access management, user management, authorization management, resource management, and security protection, Shanghai has promoted the integration of dedicated networks and information systems in various departments and areas. It has also established cross-department collaboration mechanisms and provided the technical foundation for cross-department and cross-level work.
4. *Application ecosystem*. Shanghai has taken the lead in exploring and advancing the open use of public data since 2012. Focusing on social credit, medical, health, inclusive finance and other fields, Shanghai has established a Big Data Joint Laboratory and cooperated with various social entities to launch policy applications and build the ecosystem. This ecosystem has increased public participation and created a number of of smart city scenarios.

4.3 AMERICAS

4.3.1 Columbus, United States of America[70] [71]

Columbus is the state capital of Ohio, USA and the country's fourteenth largest city. Several colleges and universities are situated in and around the city, making it a natural environment for innovation and technological research.

Columbus won the U.S. Department of Transportation's first-ever Smart City Challenge. This led to further investment in its Smart Columbus programme, which spearheaded implementation of the Smart Columbus Operating System.

The system is a unified digital platform that integrates all of the city's smart applications and generated data. The platform collects and integrates data related to "physical infrastructure (roads, traffic signal systems), various modes of transport (such as mass transit) and transportation service providers (aggregators and others)"[72].

The platform stores over 3,000 datasets at present, including:

- Traffic characteristics.
- City infrastructure inventory.
- Crash records.
- Weather readings.
- Emergency response times.
- Food services.
- Parking locations.
- Health behaviour.

All data is secure, anonymized and open to the public, all Columbus city agencies, academic researchers, industry start-ups and application developers. By visualizing the data and making it accessible to all, the platform enables insights for city officials, data scientists, private-sector research and innovation stakeholders, etc. and allows for the development of tools and pilot projects based on the data.

4.3.2 Kingston, Canada[73]

Kingston is a historic medium-sized Canadian city situated on Lake Ontario. It boasts of a diversified economy and access to higher education and research institutions, advanced health care facilities, affordable living and tourism opportunities.

To realize its smart city vision, the *Kingston City Council* has formed a public-private partnership with a leading Canadian telecommunications provider to avail of its new Smart City Platform and IoT application offerings. The aim is to leverage the data-driven opportunities that digital transformation provides in order to create a more mobile, liveable, efficient, prosperous, collaborative and environmentally sustainable smart city.

Complemented by advanced fibre and wireless broadband networks, the platform will provide city staff "a comprehensive and consolidated view of connected city services supporting better-operating efficiencies, cost savings and improved services for Kingston residents, businesses and visitors"[74]. The platform will achieve this by combining data from several IoT monitoring solutions coupled with the city's open data.

The solutions that have been rolled out as part of the pilot programme include:

- "Energy management: Energy analytics help reduce carbon emissions and meet municipal environmental targets while providing financial savings and enhanced productivity of staff through better-coordinated maintenance.

- Digital kiosks: Bridging the digital divide by providing Wi-Fi access, real-time event updates, charging station services, tourism promotion, remotely managed video cameras, city information and 9-1-1 emergency buttons[75].

4.3.3 Las Condes, MR (Metropolitan Region), Santiago de Chile

In the first stage, Las Condes contemplated the replacement of 22,000 lights, each with a motion sensor, out of the 42,000 that exist in the commune. More than 2,000 additional sensors with a multiplicity of functions that connect to the luminaires were also installed. The sensors also measure congestion by detecting the number of vehicles on the road and the speed at which they are moving. Added to this are another 400 sensors that measured air quality, 300 that control automatic irrigation based on climatic data, and 300 more sensors that measure noise levels in certain sectors of the commune. All this data is online for the community.

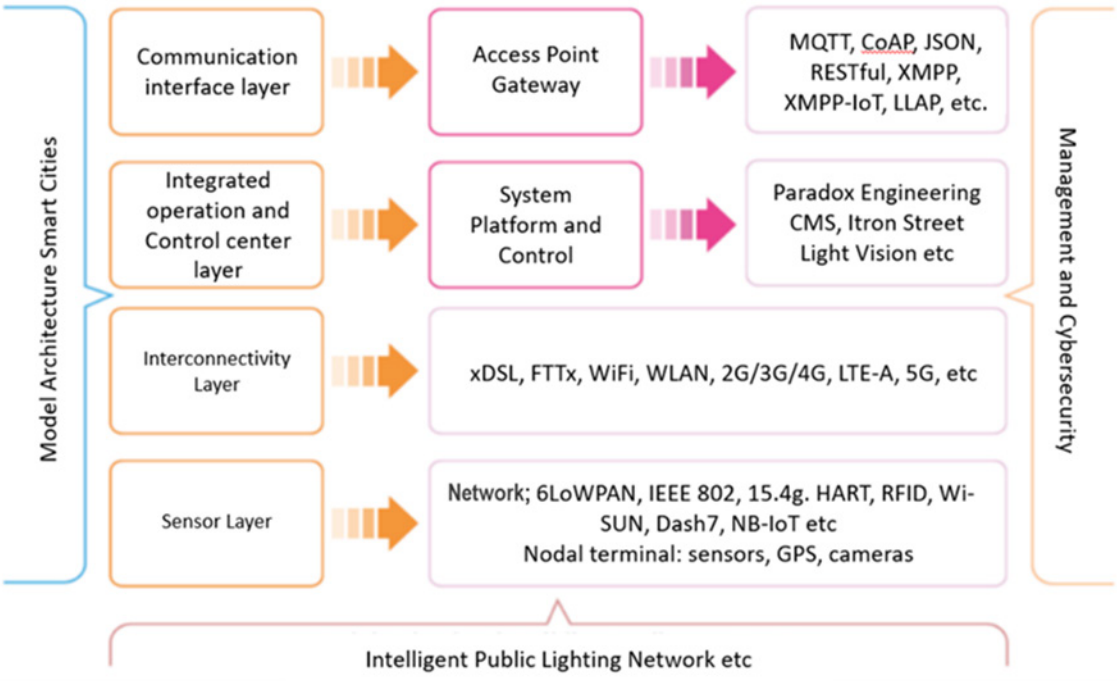
The Open Smart City programme considered the following innovations, among others:

- Collect information from the city, citizens and companies, complying with pertinent privacy requirements.
- Distribute the information so that it can be processed by those responsible for different municipal services, such as waste management, environmental safety, mobility parking, traffic and public transport, emergency management and public order, and smart meters for water, gas, electricity.
- Analyse the information according to the defined criteria.
- Make decisions by returning the refined information to the systems in charge of executing the different actions.
- Exposing data and capabilities to developers to facilitate the creation of an ecosystem of applications on the platform, which creates additional value for the citizen.

Figure 22 presents a proposal for an Open Smart City Enabling Infrastructure from the Smart Public Lighting Network to be applied in Chile showing an architecture corresponding to the information and communication technology realm of an Open and Sustainable Smart City, emphasizing the Smart Public Lighting Network (RAPI). The proposed architecture consists of the following layers: Intelligent Public Lighting Network (RAPI), layer of sensors and connected devices, interconnectivity layer, layer of Integrated Operation and Control Centres as well as an application layer and communication interfaces.

The technology to implement a technological architecture of an Open Smart City must be modular and expandable with widely adopted open standards, which can be combined with other platforms and connected with the population through user-friendly applications. Municipalities and cities can benefit from an Internet of Things (IoT) connectivity infrastructure that enables the development of smart solutions in a ubiquitous way.

Figure 22: Architecture model proposed for an Intelligent Public Lighting Network (RAPI) from the point of view of communications[76]



In the development of technological solutions and digital services for the construction of an Open Smart City in the municipalities and cities of Chile, it is necessary to build an adequate legal framework, establish short and long-term policies and structures that allow for the proper governance of these smart territories (cities and municipalities), as well as public programmes and public-private alliances that financially support their implementation. The existing legal framework in the country is of great importance for the development of Open Smart Cities projects.

A major barrier to the implementation of these projects is financial sustainability. Tax revenues are not always adequate, especially in municipalities and, therefore, it is not easy to sustain the costs of the proposed solutions. In Chile, the Corfo initiative for the development of the Enabling Infrastructure of Open Smart Cities is based on the use of the ubiquitous networks of public lighting systems. Adequate investment is needed for the development of the Open Smart City projects.

4.3.4 Markham, Canada[77] [78]

The city of Markham is located in Ontario (Canada), close to the financial and cultural hub of Toronto.

It has created a partnership with one of the leading telecommunication services providers on a smart city initiative to improve city operations and sustainability as part of the *Smart City Accelerator*

Research Programme. The partnership will result in "solutions for municipal asset monitoring, flood and water leak detection, environmental monitoring and energy management"[79], each of which will be integrated within a new smart city platform.

The platform is expected to provide a "consolidated view of connected devices across the city for better operational efficiencies, cost savings and improved services benefiting Markham's residents, businesses and visitors"[80].

Initiatives within the *Markham Smart City* programme include:

- "Asset management – Remote tracking of usage and location of municipal equipment.
- Water leak detection – Sensors on water mains and hydrants to provide real-time status of water system conditions.
- Storm/flood water monitoring – Manhole and river sensors measure water levels to help manage flood risk and mitigate damage.
- Environmental monitoring – Temperature and humidity sensors from fixed locations across the city will provide weather data to guide decisions on management of city operations.
- Energy management – Sensors will monitor and support analysis of energy usage in municipal buildings to optimize energy management."[81]

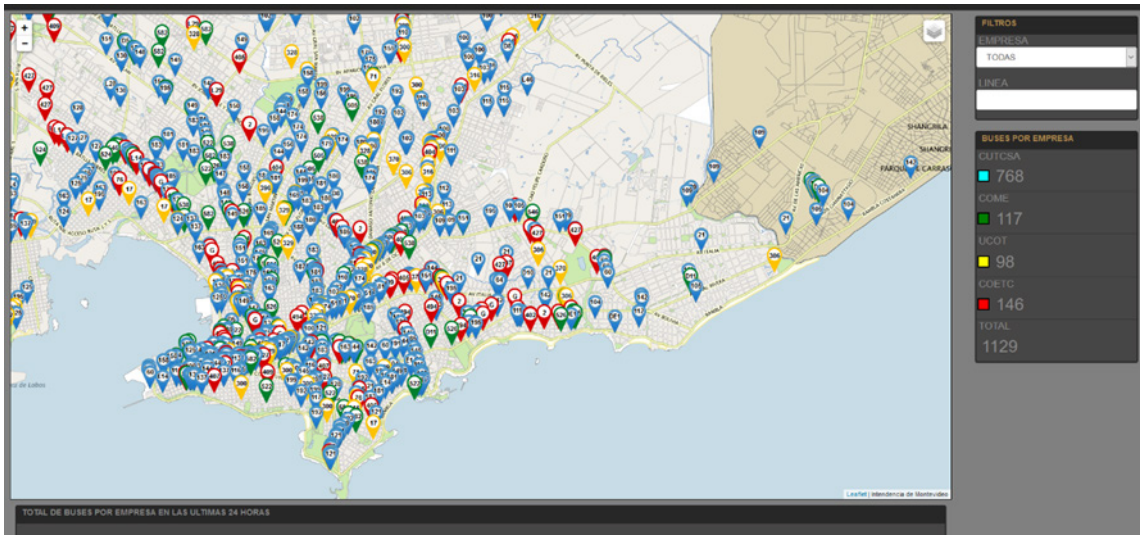
The platform will enable the city to serve as a living lab and innovation incubator that tests various sensor technologies in different business areas.

4.3.5 Montevideo, Uruguay

Montevideo is projected as a smart city that seeks to improve the quality of life of its citizens with an inclusive and sustainable approach using innovative solutions to encourage participation, promote environmental care and develop quality public services. The city and the country stand out for their quality of life thanks to a series of policies implemented in recent years:

- The civil rights agenda, diversity and tolerance are watchwords, with an emphasis on care for the environment are central elements.
- Innovation and technology are also central elements as levers to productive development, rational use of resources, citizen participation and the enjoyment of leisure time.
- The Montevideo Decide (Decides Montevideo), a digital platform for direct participation by citizens, and the "Participatory Budget" for projects proposed and selected by citizens encourage citizens to interact and participate in decision-making and in the implementation of public policies with a gender perspective in a transparent, two-way dialogue. There are no smart cities without smart and engaged citizens.

Figure 23: Montevideo public transport GIS



The use of transversal platforms, the Internet of Things, data science and artificial intelligence allows all areas of the organization to be managed with advanced technological tools and to offer quality services to citizens. Data is the oil of our time; its ownership, availability, preservation and use for the improvement of services are a great responsibility. An example of this is shown in the Montevideo public transport GIS project. (Figure 23).

Finally, sustainability and resilience are amongst the most important challenges, minimizing the environmental impact in the present while also focusing on future generations, promoting the necessary change of habits and customs along with the introduction of good management practices. The reference framework of "Montevideo Inteligente" constitutes a milestone towards the future development of a diverse, innovative, enterprising, enjoyable and liveable city.

4.3.6 Orillia, Canada[82]

The city of Orillia, a small city (with a population of less than 50,000) in Ontario (Canada), has launched an initiative to develop into a model smart city within the province and country. It has formed a partnership with a leading telecommunications provider that offers smart city platforms to implement:

- Digital kiosks that provide local waypoints and directories of local businesses, and highlight community events to enhance visitor experience, increase citizen engagement and stimulate tourism within the city, in order to promote local businesses.
- Public Wi-Fi network.
- Fleet management solutions optimizing routes and managing vehicles more efficiently, while providing real-time updates to residents to monitor city snow ploughing progress online.

- Water monitoring and groundwater inward seepage detection solutions that identify the volume of groundwater infiltration into the city's sanitary sewer system, thereby reducing the unnecessary treatment of groundwater.

The *City of Orillia* will also be implementing the telecommunications provider's smart city platform to aggregate data and provide a comprehensive view of the connected solutions. The telecommunications provider will, in turn, invest in fibre connectivity for residences and businesses in Orillia. The mutual partnership will give Orillia the opportunity to run a pilot to explore other IoT applications from the telecommunications provider in "a cost-effective manner in the areas of application development, data collection and data analysis"[84].

5 Key takeaways and conclusions

The experiences derived from the smart cities covered in this report provide some interesting insights into where the "smart city platform market" is at present, some of the barriers that cities face which lead 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.

5.1 Geographic distribution

In terms of geographical proliferation, North America currently leads the overall smart city platform implementation market. As seen in the cases of multiple smart to medium-sized Canadian cities, these cities do not experience some of the common barriers to investing in city platforms that even cities of comparable characteristics in Europe face. Part of the reason is that there appears to be greater support at the national level for smart city programmes in North America and, hence, more funds are available to cities for investing in smart solutions.

The *Smart Cities Marketplace*, promoted by the European Union, is a major market-changing undertaking supported by the European Commission, bringing together cities, industries, SMEs, investors, researchers and other smart city actors[85].

Fostering and supporting local innovation at the national or regional level has also led to successful outcomes in certain cities in Europe. Spain is seeing multiple cities adopt comprehensive city-wide smart platforms that synergistically build off similar experiences.

Similar outcomes can be observed in the UAE and Australia. The sharing of resources, expertise, use cases and lessons learned within a country or region can benefit other cities in the vicinity tremendously. It leads to tried-and-tested roadmaps and blueprints for replication and adaptation in other cities.

This also makes global initiatives, such as United for Smart Sustainable Cities (U4SSC), valuable due to their role as connectors and spot lighthouse of cities and communities as well as facilitators of inter-city and regional collaboration and knowledge-sharing.

5.2 Governance

Project and city initiatives are usually managed in the local government by vertically structured departments. These municipal departments usually work in vertical city silos. However, smart city projects are generally multidisciplinary and involve different areas of the organization, as well as collaboration with external stakeholders.

The creation of a *smart city office*, made up of a multidisciplinary team, can be a guarantee to align the city's vision, strategy along with policies for the digital transformation of municipal services, the unified management of information and normalized relationship with external agents.

Unified governance around the *city data platform* becomes an opportunity to drive smart city transformation. Unified information, 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.

Cooperation and collaboration between the public-private domains will be essential as cities continue to evolve into increasingly complex systems

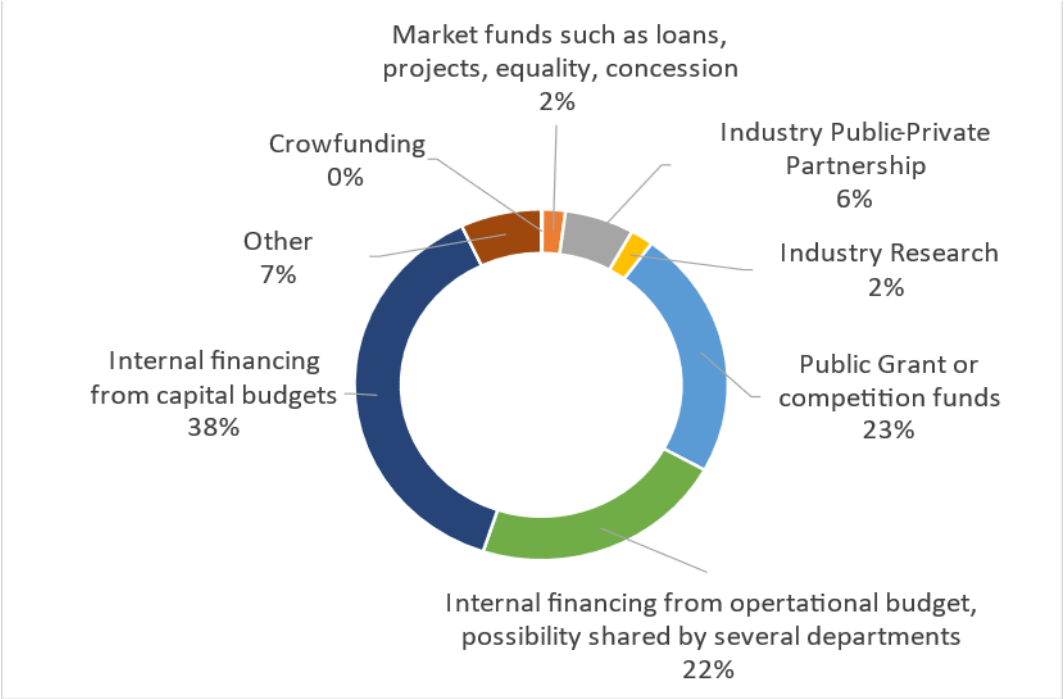
5.3 Economic sustainability

Corporations and governments with a limited budget must satisfy the local services demanded by citizens. The project of a smart city platform requires a large amount of investment and significant operational costs. Common finance sources for carrying out Smart city projects are public budget and Public-Private Partnerships (PPP). Other innovative financing instruments proposed are crowdfunding, earmarking government funding, monetizing the local data collected, recoverable investment funds, etc.[86]

There is a considerable difference between European municipalities and smart cities in India, China or the US which are normally financed by national governments and private funding. But for European local governments one of the most significant sources of financing projects are European Union programmes. Within the EU, specific initiatives supported by the European Commission, such as the "European Innovation Partnership on Smart Cities and Communities" (EIP-SCC) provides clear and practical information about opportunities of European funding (European Structural Investment Funds, the European Investment Bank's financial instruments as well as several programmes managed by the European Commission and Member States[87].

As an example, Figure 24 shows different financing structures that municipalities in the EU have used for the commissioning and operational support of their city platforms[88].

Figure 24: Mechanisms of financing EU city platforms



Data is turning into an important asset for the economy, hence data-driven innovation is essential for economic growth in smart cities. Urban data platforms collected data from different sources and its exploitation can create value in many sectors, impulse research and innovation as well as leading to more business opportunities and increased availability of knowledge capital[89]. Therefore, data is more valuable than ever before, and cities need to explore options to monetize it and can be a new revenue source for local governments that would help them to become self-sustainable and maintain smart infrastructure.

The European Commission aims to create a single market for data, where data from public bodies, business and citizens can be used safely and fairly for the common good. Data Sharing Initiative[90] will draw up rules for common European data spaces covering areas like the environment, energy and agriculture, to:

- Make better use of publicly held data for research for the common good.
- Support voluntary data sharing by individuals.
- Set up structures to enable key organizations to share data.

5.4 Common barriers

A barrier to smart city platform implementation that was identified from the experiences of cities that participated in the U4SSC elicitation exercise is that for cities of a certain size, a city-wide

platform can be too complex an undertaking, both financially and operationally. In such cases, the costs outweighed the benefits of eliminating departmental silos and integrating city management functions.

This can be mitigated through a holistic vision. If a city considers the implementation of a smart city platform to be an eventual goal, it can deploy smart solutions smaller in scope strategically and thoughtfully without breaking established systems. This can lead to the possibility of simply scaling or building such solutions further into a unified platform in the future when such an undertaking is feasible.

However, cities employing such a long-term approach should avoid the trap of working too long in patchworks, fragments, or silos, as doing so will not yield the results that are required for smart and efficient cities to address the challenges of an increasingly digitized global landscape. The business case for smart city platform implementation should continue to be reviewed, updated, and prioritized for discussion.

Another proven way that cities can advance on their smart technology trajectory is through establishing public-private partnerships. This especially allows cities with constrained budgets and resources to share the costs of deployment with partners, instead of facing it all upfront. While it may lead to longer implementation horizons, more involved and complex decision processes, and a greater need for buy-in from a larger and more diverse set of stakeholders, a city could achieve end outcomes similar to if it had complete fiscal and project ownership.

Other key barriers and restricting factors are legislation (public procurement), privacy concerns and cybersecurity risks. Public administrations usually use public procurement as a tool to transform a smart and sustainable city as well as the use of bidding to achieve transparency and enhance accountability. Smart city solutions are multi-component systems, so their procurement may sometimes be complex, and city governments sometimes are not prepared to ensure the best value for money. Also, the lack of professional knowledge to evaluate complex proposals about this innovative solution may present problems.

To avoid this, municipalities can collaborate with companies in the early stages and define the purpose of the tender. Moreover, it is recommended to use open calls and/or competitive dialogue as well as to involve more sustainability criteria in the tender. Besides, there is the possibility to outsource the main tendering process, but this is not an allowed procedure in some countries.

Public procurement in the EU has been influenced by public sector procurement directives: Directive 2014/24/UE and Directive 2014/25/UE. These Directives introduce new processes that aim to reduce complexities. EU legislation to ensure transparent procurement processes and free and open competition in the bidding process limits the municipal authority's ability to interact with the private and the civil sector.

In an urban data platform, it is essential adopt adequate measures to secure user privacy and sensitive information so that smart city initiatives are not compromised. Europe's General Data

Protection Regulation (GDPR) and the California Consumer Privacy Act (CCPA) are centralizing privacy standards for users around the world. GDPR is designed to harmonize privacy laws across Europe. In most cases, cities have not yet developed an appropriate cybersecurity plan at the local level. However, while this may be an expensive process, it is a compulsory step as data must be stored in a secured manner.

Table 2 summarizes, by relevance, the main obstacles identified in the implementation of a city platform[91].

Table 2: SCP non-technical barriers

Non-technical barriers	Relevance
Governance	
Impact of policy swings and changing political priorities of a long-term strategy of service innovation. Dependence on corporate interest.	++
Fragmented authority and lack of leadership	+++
Silos and administrative conflicts. Poorly coordinated between different levels of governments.	+++
Legislative framework and outdated rules hamper smart city initiatives. Long public procurement processes	+++
Low economic resource, the knowledge, competence and technology access	++
Financial	
Limited budget and financial restrictions for smart city initiatives	+++
Weak business model	+
High initial costs and questionable profitability	+
Intangible benefits and difficulty to monetize on smart city investments	++
Social and cultural	
Lack of professional skills	++
Insufficient awareness or interest of citizens	++

5.5 Key success factors, criteria and final considerations

Cities worldwide have vastly differing backgrounds, priorities, capabilities, strengths, and strategic goals and objectives, which means that there can never be a one-size-fits-all overarching solution to their smartness and sustainability needs.

Even so, cities can build and foster certain qualities that can help them leverage standard off-the-shelf solutions and avoid investing in costly platform development from scratch. One such quality is a consistent commitment to smart initiatives at the top levels of governance and leadership. Having clear smart goals and objectives and the alignment of stakeholders' expectations are also crucial success factors.

In the experience of many cities covered in this report, successful smart city platform implementation hinges on keeping citizens' needs, quality of life requirements, and expectations first and foremost. This can be achieved by developing sound citizen engagement and democratic mechanisms that allow the public and all other key stakeholders to have a say in the general urban direction-setting.

A key consideration is how the smart city platform should be utilized in terms of data management. Without prior understanding at the city-level of how it will make the best use of the data that is generated by smart solutions to flow into the platform, it will offer limited to no functional utility. Again, strategic and thoughtful deployment decisions will go a long way to ensuring returns on the city's investment into its smart city platform.

The International Telecommunication Union (ITU) and other standardization bodies offer valuable information and guidance to cities in their smart transformation. Initiatives such as U4SSC can help cities as guidance in this process.

Lastly, safety, security and data privacy must be key considerations for any city looking to implement city platforms and other smart solutions. Ethical and legal concerns about use of data such as mobile location and facial recognition must be addressed for the public transparently and objectively. This is especially crucial in scenarios where smart city platform initiatives are sponsored, overseen, and administered by different actors, funding mechanisms and policies.

Endnotes

1 Schaffers, Hans, et al. "Smart Cities and the Future Internet: Towards Cooperation Frameworks for Open Innovation." The Future Internet Lecture Notes in Computer Science, 2011, pp. 431–446., doi:10.1007/978-3-642-20898-0_31.

2 ITU. "Recommendation ITU-T Y.4900: 'Overview of Key Performance Indicators in Smart Sustainable Cities.' 2016, doi: https://www.itu.int/rec/T-REC-L.1600.

3 ITU. "ITU-T, Smart Sustainable Cities at a Glance." www.itu.int/en/ITU-T/ssc/Pages/info-ssc.aspx.

4 UNE 178201:2016, Smart cities. Definition, attributes and requirements, https://www.en.aenor.com/normas-y-libros/buscador-de-normas/UNE?c=N0056504.

5 Elmangosh, Asma, et al. "Design Aspects for a Reference M2M Communication Platform for Smart Cities." 2013 9th International Conference on Innovations in Information Technology (IIT), IEEE, 2013, www.academia.edu/18033750/Design_Aspects_for_a_Reference_M2M_Communication_Platform_for_Smart_Cities.

6 ITU. "Recommendation ITU-T Y.4900: 'Overview of Key Performance Indicators in Smart Sustainable Cities.'" 2016, doi: https://www.itu.int/rec/T-REC-L.1600.

7 IEEE Initiatives enabling smart and secure data management.

8 B. Cohen, "Why Exactly Is A Smart City?" Fast Company (September 19, 2012) http://www.fastcoexist.com/1680538/what-exactly-is-a-smart-city Accessed April 26, 2021. [Google Scholar].

9 https://sdgs.un.org/2030agenda

10 Elmangosh, Asma, et al. "Design Aspects for a Reference M2M Communication Platform for Smart Cities." 2013 9th International Conference on Innovations in Information Technology (IIT), IEEE, 2013, www.academia.edu/18033750/Design_Aspects_for_a_Reference_M2M_Communication_Platform_for_Smart_Cities.

11 ITU. "Recommendation ITU-T Y.4200: 'Requirements for the interoperability of smart city platforms." 2018, https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-Y.4200-201802-I!!PDF-E&type=items.

12 ITU. "Recommendation ITU-T Y.4200: 'Requirements for the interoperability of smart city platforms." 2018, https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-Y.4200-201802-I!!PDF-E&type=items.

13 Santana, Eduardo Felipe Zambom, et al. "Software Platforms for Smart Cities: Concepts, Requirements, Challenges, and a Unified Reference Architecture." ACM Computing Surveys, vol. 50, no. 6, 2018, pp. 1–37., doi:10.1145/3124391.

14 O'Brien, Larry. "Smart City Platform Strategies." ARC Advisory Group, 28 Jan. 2020, www.arcweb.com/blog/smart-city-platform-strategies.

15 ITU. "Recommendation ITU-T Y.4200: 'Requirements for the interoperability of smart city platforms." 2018, https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-Y.4200-201802-I!!PDF-E&type=items.

16 Hernández, José L. García, Rubén. Fischer, Michael. Schonowski, Joachim. Atlan, Daniel. Ruohomäki, Timo. "An interoperable Open Specifications Framework for Smart City urban platforms". 2019 Doi: 10.1109/GIOTS.2019.8766396

17 Zambom Santana, Eduardo Felipe. Chaves, Ana Paula. Gerosa, Marco Aurelio. Kon, Fabio. Milojicic, Dejan "Software Platforms for Smart Cities: Concepts, Requirements, Challenges, and a Unified Reference Architecture" 2016. Doi: 10.1145/3124391

18 EEIP "Smart City Guidance Package" 2019. Doi: https://smart-cities-marketplace.ec.europa.eu/news-and-events/news/2019/smart-city-guidance-package.

19 Schaffers, Hans, et al. "Smart Cities and the Future Internet: Towards Cooperation Frameworks for Open Innovation." The Future Internet Lecture Notes in Computer Science, 2011, pp. 431–446., doi:10.1007/978-3-642-20898-0_31.

20 Greater Cambridge Partnership. "Smart Cambridge 2019 - 2020." 2019, www.connectingcambridgeshire.co.uk/wp-content/uploads/2019/09/Smart-Cambridge-brochure-2019-2020.pdf.

21 Greater Cambridge Partnership. "Smart Cambridge 2019 - 2020." 2019, www.connectingcambridgeshire.co.uk/wp-content/uploads/2019/09/Smart-Cambridge-brochure-2019-2020.pdf.

22 Greater Cambridge Partnership. "Smart Cambridge 2019 - 2020." 2019, www.connectingcambridgeshire.co.uk/wp-content/uploads/2019/09/Smart-Cambridge-brochure-2019-2020.pdf.

23 Smart Cities World. Cambridge Partners in the Urban Data Project. 6 Feb. 2019, www.smartcitiesworld.net/news/news/cambridge-partners-in-the-urban-data-project-3827.

24 Thinking Cities: IoT Agents (IoTA). https://thinking-cities.readthedocs.io/en/latest/device_gateway/index.html.

25 Gjøvik Kommune. "About Gjøvik." 2020, https://www.gjovik.kommune.no/om-gjovik/.

26 Secretariat, OASC. "Lisbon's Bet on Urban Data Platform." Open & Agile Smart Cities, 12 Dec. 2019, oascities.org/lisbons-bet-on-urban-data-platform/.

27 NEC Smart City. "Lisbon, Portugal Integrated Management and QoL." www.necsmartit.com/lisbon-portugal/#1523486160190-ec551f30-e34f8a58-37c0.

28 NEC. "NEC's Intelligent Management Platform Makes Lisbon Smarter." 4 Oct. 2019, www.asmag.com/showpost/30622.aspx.

29 NEC Smart City. "Lisbon, Portugal Integrated Management and QoL." www.necsmartit.com/lisbon-portugal/#1523486160190-ec551f30-e34f8a58-37c0.

30 NEC Smart City. "Lisbon, Portugal Integrated Management and QoL." www.necsmartit.com/lisbon-portugal/#1523486160190-ec551f30-e34f8a58-37c0.

31 smart.pully.ch.

32 Ville de Pully. "Projects." 2020, smart.pully.ch/en/projects/.

33 OECD. "The Co-Operative Model in Trentino – Italy: A Case Study." 2014, www.oecd.org/cfe/leed/150202%20The%20cooperative%20model%20in%20Trentino_FINAL%20with%20covers.pdf.

[34] City of Valencia. "VLCi Platform: València Smart City FIWARE Information Repository." 2020, http://smartcity.valencia.es/vlci/vlci-platform/.

[35] https://www.missionsvalencia.eu/social-urban-innovation/.

[36] http://smartcity.valencia.es.

[37] City of Valencia. "Smart City Office." 2020, smartcity.valencia.es/smart-city-office/.

[38] City of Valencia. "Portal Transparència i Dades Obertes." 2020, gobiernoabierto.valencia.es/va/.

[39] City of Valencia. "AppValència." 2020, www.valencia.es/appvalencia/.

[40] City of Valencia. "IMPULSO VLCi – Dosier Informativo." 2017, www.red.es/redes/sites/redes/files/valencia.pdf.

[41] D'mello, Anasia. "Abu Dhabi Completes Smart City Project Using Software AG's Cumulocity IoT." IoT Now, 22 Oct. 2018, www.iot-now.com/2018/10/22/89640-abu-dhabi-completes-smart-city-project-using-software-ags-cumulocity-iot/.

[42] D'mello, Anasia. "Abu Dhabi Completes Smart City Project Using Software AG's Cumulocity IoT." IoT Now, 22 Oct. 2018, www.iot-now.com/2018/10/22/89640-abu-dhabi-completes-smart-city-project-using-software-ags-cumulocity-iot/.

[43] World Future Energy Summit 2022. Abu Dhabi and Dubai Expand Their Smart City Horizons This Year. www.worldfutureenergysummit.com/en-gb/future-insights-blog/abu-dhabi-and-dubai-expand-their-smart-city-horizons-this-year.html.

[44] Profit From IoT. "Honeywell Selected For India's Auric and Faridabad Smart City Projects." 10 Sept. 2019, iot.electronicsforu.com/headlines/honeywell-provides-technologies-for-indias-auric-and-faridabad-smart-city-projects/.

[45] The Week. "AURIC: Aurangabad Industrial City." The Week, 21 Sept. 2019, https://www.theweek.in/news/biz-tech/2019/09/21/auric-aurangabad-industrial-city.html.

[46] Profit From IoT. "Honeywell Selected For India's Auric and Faridabad Smart City Projects." 10 Sept. 2019, iot.electronicsforu.com/headlines/honeywell-provides-technologies-for-indias-auric-and-faridabad-smart-city-projects/.

[47] Profit From IoT. "Honeywell Selected For India's Auric and Faridabad Smart City Projects." 10 Sept. 2019, iot.electronicsforu.com/headlines/honeywell-provides-technologies-for-indias-auric-and-faridabad-smart-city-projects/.

[48] The Week. "AURIC: Aurangabad Industrial City." The Week, 21 Sept. 2019, https://www.theweek.in/news/biz-tech/2019/09/21/auric-aurangabad-industrial-city.html.

[49] The Department of Infrastructure, Transport, Regional Development and Communications. "Australia's First Heritage City Becomes an Australian Future City." Australian Government, 3 Dec. 2020, www.infrastructure.gov.au/cities/smart-cities/collaboration-platform/australias-first-heritage-city-becomes-an-australian-future-city.aspx.

50 Department of Agriculture, Water and the Environment. "National Heritage Places - City of Broken Hill." Australian Government, 20 Jan. 2015, www.environment.gov.au/heritage/places/national/city-broken-hill.

51 The Department of Infrastructure, Transport, Regional Development and Communications. "Australia's First Heritage City Becomes an Australian Future City." Australian Government, 3 Dec. 2020, www.infrastructure.gov.au/cities/smart-cities/collaboration-platform/australias-first-heritage-city-becomes-an-australian-future-city.aspx.

52 NXN. "The Backbone of Smart Cities – How Smart Dubai Platform Is Enabling an Agile Data-Driven City." 2017, https://nxn.ae/wp-content/uploads/2021/02/WP-Dubai-Smart-city-Platform-v9-3rd-Jan.pdf.

53 NXN. "The Backbone of Smart Cities – How Smart Dubai Platform Is Enabling an Agile Data-Driven City." 2017, https://nxn.ae/wp-content/uploads/2021/02/WP-Dubai-Smart-city-Platform-v9-3rd-Jan.pdf.

54 NXN. "The Backbone of Smart Cities – How Smart Dubai Platform Is Enabling an Agile Data-Driven City." 2017, https://nxn.ae/wp-content/uploads/2021/02/WP-Dubai-Smart-city-Platform-v9-3rd-Jan.pdf.

55 NXN. "The Backbone of Smart Cities – How Smart Dubai Platform Is Enabling an Agile Data-Driven City." 2017, https://nxn.ae/wp-content/uploads/2021/02/WP-Dubai-Smart-city-Platform-v9-3rd-Jan.pdf.

56 NXN. "The Backbone of Smart Cities – How Smart Dubai Platform Is Enabling an Agile Data-Driven City." 2017, https://nxn.ae/wp-content/uploads/2021/02/WP-Dubai-Smart-city-Platform-v9-3rd-Jan.pdf.

57 WSPglobal. "Newcastle to Implement Smart City Intelligent Platform." 18 June 2019, www.wsp.com/en-AU/news/2019/newcastle-smart-city-intelligent-platform.

58 Tourism Australia. "Guide to Newcastle." www.australia.com/en-ca/places/sydney-and-surrounds/guide-to-newcastle.html.

59 WSPglobal. "Newcastle to Implement Smart City Intelligent Platform." 18 June 2019, www.wsp.com/en-AU/news/2019/newcastle-smart-city-intelligent-platform.

60 WSPglobal. "Newcastle to Implement Smart City Intelligent Platform." 18 June 2019, www.wsp.com/en-AU/news/2019/newcastle-smart-city-intelligent-platform.

61 WSPglobal. "Newcastle to Implement Smart City Intelligent Platform." 18 June 2019, www.wsp.com/en-AU/news/2019/newcastle-smart-city-intelligent-platform.

62 WSPglobal. "Newcastle to Implement Smart City Intelligent Platform." 18 June 2019, www.wsp.com/en-AU/news/2019/newcastle-smart-city-intelligent-platform.

63 GovTech Singapore. "Factsheet – Smart Nation Platform." www.tech.gov.sg/files/products-and-services/5-SmartNation-Platform-Factsheet.pdf.

64 GovTech Singapore. "Factsheet – Smart Nation Platform." www.tech.gov.sg/files/products-and-services/5-SmartNation-Platform-Factsheet.pdf.

65 GovTech Singapore. "Factsheet – Smart Nation Platform." www.tech.gov.sg/files/products-and-services/5-SmartNation-Platform-Factsheet.pdf.

66 iDA Singapore. "Media Factsheet – Smart Nation Platform." Apr. 2015, www.imda.gov.sg/~/media/imda/files/inner/about%20us/newsroom/media%20releases/2015/0422_snv/annexa.pdf?la=en&hash=44CA15802F5E1C3033735DB37C122369.

67 Bhunia, Priyankar. "Updates on Smart Nation Sensor Platform." OpenGov Asia, 27 Oct. 2017, opengovasia.com/updates-on-smart-nation-sensor-platform-connecting-all-110000-lampposts-in-the-city-video-analytics-pilot-in-2nd-half-of-2017/.

68 Bhunia, Priyankar. "Updates on Smart Nation Sensor Platform." OpenGov Asia, 27 Oct. 2017, opengovasia.com/updates-on-smart-nation-sensor-platform-connecting-all-110000-lampposts-in-the-city-video-analytics-pilot-in-2nd-half-of-2017/.

69 Virtual Singapore https://www.nrf.gov.sg/programmes/virtual-singapore

70 Eggers, William D., et al. "Delivering the Digital City: Best-in-Class Customer Experience." Deloitte Center for Government Insights, 2018, www2.deloitte.com/bd/en/pages/public-sector/articles/gx-delivering-digital-city-customer-experience-smart-cities.html#.

71 The City of Columbus. "About Smart Columbus." Smart Columbus, www.smartcolumbusos.com/about/about-smart-columbus.

72 Eggers, William D., et al. "Delivering the Digital City: Best-in-Class Customer Experience." Deloitte Centre for Government Insights, 2018, www2.deloitte.com/bd/en/pages/public-sector/articles/gx-delivering-digital-city-customer-experience-smart-cities.html#.

73 Bell Canada Enterprises. "Bell and City of Kingston Partner for Smart City Programme." 7 Feb. 2018, www.bce.ca/news-and-media/releases/show/Bell-and-City-of-Kingston-partner-for-Smart-City-program-1.

74 Bell Canada Enterprises. "Bell and City of Kingston Partner for Smart City Programme." 7 Feb. 2018, www.bce.ca/news-and-media/releases/show/Bell-and-City-of-Kingston-partner-for-Smart-City-program-1.

75 Bell Canada Enterprises. "Bell and City of Kingston Partner for Smart City Programme." 7 Feb. 2018, www.bce.ca/news-and-media/releases/show/Bell-and-City-of-Kingston-partner-for-Smart-City-program-1.

76 "Model Master Plan for the Development of Enabling Infrastructure of an Open Smart City". ACTI-CORFO, September 2020 available at http://repositoriodigital.corfo.cl/xmlui/handle/11373/10242.

77 Bell Canada. "Bell Continues to Make Canadian Cities Smarter." business.bell.ca/shop/medium-large/internet-of-things/smart-cities/markham#INT=EMOB_hmpg_BAN_Markham_020519_HC.

78 Bell Canada Enterprises. "City of Markham and Bell Partner for Smart City Initiative." 6 Feb. 2019, www.bce.ca/news-and-media/releases/show/City-of-Markham-and-Bell-partner-for-Smart-City-initiative-1.

79 Bell Canada. "Bell Continues to Make Canadian Cities Smarter." business.bell.ca/shop/medium-large/internet-of-things/smart-cities/markham#INT=EMOB_hmpg_BAN_Markham_020519_HC.

80 Bell Canada. "Bell Continues to Make Canadian Cities Smarter." business.bell.ca/shop/medium-large/internet-of-things/smart-cities/markham#INT=EMOB_hmpg_BAN_Markham_020519_HC.

81 Bell Canada Enterprises. "City of Markham and Bell Partner for Smart City Initiative." 6 Feb. 2019, www.bce.ca/news-and-media/releases/show/City-of-Markham-and-Bell-partner-for-Smart-City-initiative-1.

82 Bell Canada. "Bell and City of Orillia Smart City Research Partnership." business.bell.ca/shop/smartcities/orillia#INT=EMOB_IoT_BTN_Markham_Mass_020518_HC.

83 City of Orillia. "City of Orillia and Bell Partner on Smart City Initiative." 15 May 2018, www.orillia.ca/Modules/News/index.aspx?newsId=e259119a-7321-46ba-b706-e36588e3b5a6#.

84 City of Orillia. "City of Orillia and Bell Partner on Smart City Initiative." 15 May 2018, www.orillia.ca/Modules/News/index.aspx?newsId=e259119a-7321-46ba-b706-e36588e3b5a6#.

85 https://smart-cities-marketplace.ec.europa.eu/.

86 https://urbaninnovation.asu.edu/sites/default/files/smartcitiescouncil_-_financing_guide-3_31_14.pdf.

87 EU. Analysing the potential for wide scale roll out of integrated Smart Cities and Communities solutions. Funding/financing schemes for SCC solutions. 2016, https://smart-cities-marketplace.ec.europa.eu/action-clusters-and-initiatives/action-clusters/integrated-infrastructures-and-processes/urban-data.

88 Smart Cities Marketplace – 2019 Study on Urban Data Platforms – Key Finding (Url:https://eu-smartcities.eu/node/27933).

89 https://www.open.edu/openlearn/ocw/mod/oucontent/view.php?id=96119&section=_unit6.3.

90 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12491-Data-sharing-in-the-EU-common-European-data-spaces-new-rules-en.

91 https://smart-cities-marketplace.ec.europa.eu/sites/default/files/2019%20Study%20on%20Urban%20Data%20Platforms%20-%20key%20findings%20%286-3-2020%29.pdf.

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