CENTRO STUDI

TIM

ITALY'S SMART AND SUSTAINABLE CITIES

with the scientific contribution of

Centro Studi TIM

with the scientific contribution of

CNR Department of Engineering, ICT and Technologies for Energy and Transport - DIITET

Smart City Observatory and Startup Intelligence Observatory Politecnico di Milano

Rome, 7 March 2023

Introduction

The Smart City has become increasingly important in both public debate and the interest of investors and public institutions.

The reasons lie in the now-vast availability of technological solutions, on the one hand, and the growing interest in environmental, social, and economic sustainability that has emerged in the last decade, thanks also to the impulse of institutions such as the United Nations (UN). In Italy, the BES Project was launched in 2010 by the ISTAT, Italian National Institute of Statistics to measure fair and sustainable wellbeing, with the aim of integrating indicators of economic activities (first and foremost Gross Domestic Product (GDP)) with the dimensions of wellbeing, with measures relating to inequalities and sustainability. Its growing importance is evidenced by the fact that since 2016, BES Project has been part of economic planning.

The objectives pursued with this report are threefold:

- Illustrate the Smart City concept, its economic and social importance, the technologies and key players, as well as the prospects for development, also from a market perspective.
- explain and quantify the impacts on the urban environment and citizens' lives. Evaluating the impacts of the Smart City in economic terms can enable both public decision-makers and citizens to better understand the importance of the development and application of dedicated technologies. However, only some aspects can currently be converted into economic value due to the lack of a reference scientific literature on each of the many aspects impacted by the Smart City.
- highlight the scientific and evolutionary framework that will enable cities to become increasingly smart, providing assessment tools that enable public administrators to make effective and efficient decisions with greater awareness of the impacts on all elements of sustainability.

Thanks to the contribution of excellent partners, such as the main Italian public research institution, the National Research Council (CNR), and its Department of Engineering, ICT and Technologies for Energy and Transport (DIITET), as well as the Smart City Observatories and Startup Intelligence Observatories of the Politecnico di Milano, we have endeavored to provide a comprehensive overview of the aforementioned aspects.

Finally, it is worth remembering that the contribution of start-ups is fundamental, as they serve as a laboratory and forge of ideas and solutions that intercept known needs with innovative tools, as well as emerging needs that are new by their very nature. To support the growth of start-ups, the TIM SMART CITY CHALLENGE was proposed, and the results of which are summarized in the appendix.

Happy reading.

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CHAPTER 1

What a Smart City is

The term **Smart City** refers to a conception of urban reality that transcends technological boundaries and proposes a broad vision ranging from mobility to energy efficiency, from eGovernment to active citizen participation.

The ultimate goal of **Smart City** initiatives is to raise the standards of **sustainability, livability and economic dynamism** of the **cities of the future.**

The Smart City is a place where traditional networks and services are made more efficient with the use of digital and telecommunications technologies, benefiting its inhabitants and businesses.

However, the concept of a Smart City has evolved to encompass a wider vision that goes beyond technology. The city becomes a project towards modern, sustainable, safe, and healthy living that supports citizens and businesses in their diverse needs, whether in daily life, work, social and community participation, or relations with the public administration.

A Smart City intelligently manages resources, aims for economic sustainability and energy self-sufficiency, and prioritizes the quality of life and needs of its citizens. It is a territorial space that embraces innovation and the digital revolution, while remaining sustainable and attractive.

To achieve this, a Smart City goes beyond the use of Information and Communication Technologies (ICT) for better resource management and reduced emissions. It involves smarter urban transport networks, improved water supply and waste disposal facilities, and more efficient ways of lighting and heating buildings. It also includes a more interactive and responsive city administration, safer public spaces, and meeting the needs of an ageing population.

What a Smart City is

What it is

The Smart City is a '4.0' smart city that:

- manages resources intelligently,
- tends to become economically sustainable and energy self-sufficient,
- aims to improve the quality of life and focus on the needs of its citizens

The problems it faces

Smart cities address a diverse range of issues, including efficient transport, smart and improved buildings and homes, optimal energy use, and better administrative services.

The areas it impacts

Smart cities they impact various sectors, such as healthcare, transport, water, assisted living, security, and energy (electricity, gas, coal).

Smart City applications belong to different fields of use and impact aspects of quality of life in different ways.

These applications affect various dimensions of individuals' lives such as their work, safety, time efficiency, health, environment, ability to socialize and participate in civic activities, and cost of living.

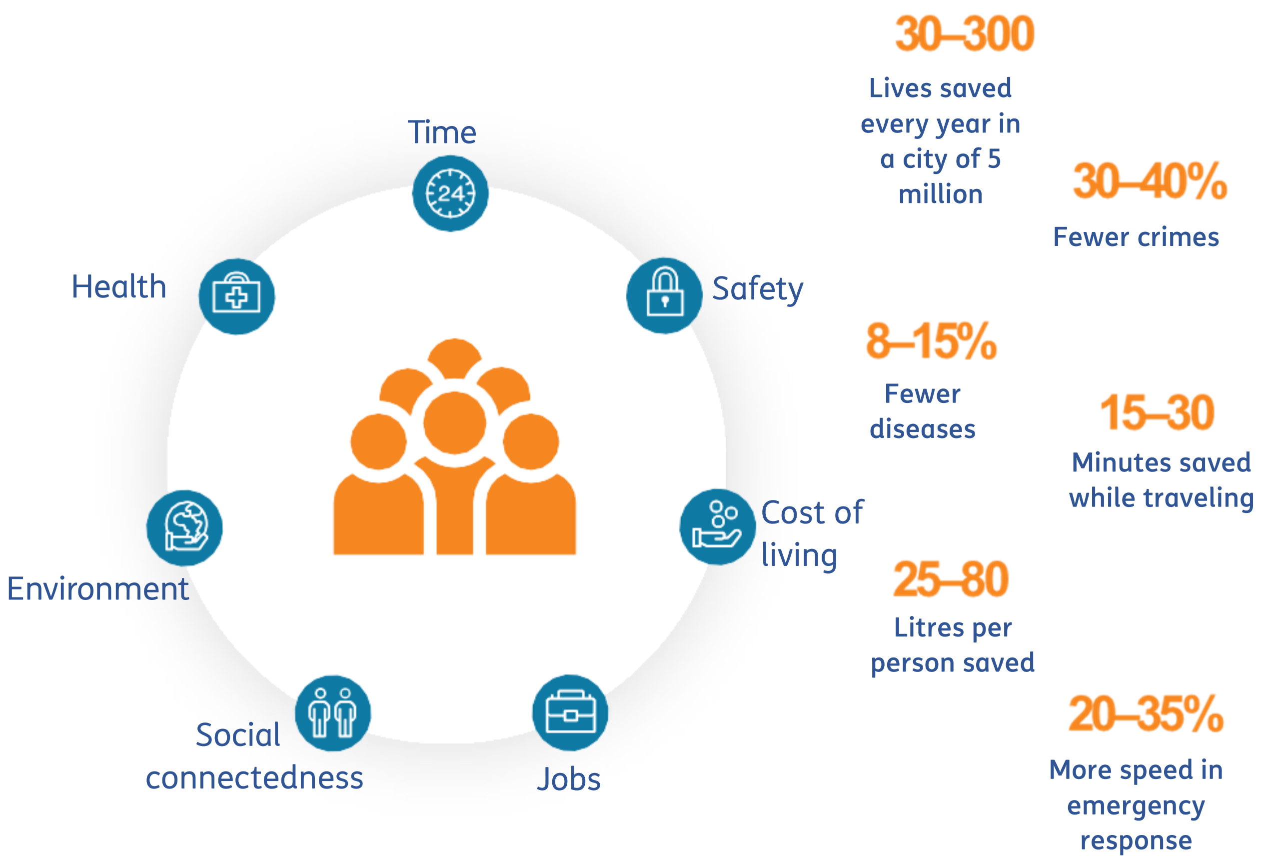
The effectiveness of these applications can be measured or estimated by considering the various urban environments in which they are deployed.

With the proliferation of sensors in urban settings, administrations can now obtain real-time information on what is happening in their cities.

While having more information does not always guarantee better urban management, the development of Big Data analysis technologies provides tools to identify critical aspects such as traffic, accidents, and safety at an early stage, plan processes such as waste collection and maintenance work better, and transform urban life to be more responsive to citizens' needs.

What a Smart City is

According to *McKinsey* & Company (*McKinsey*) urban quality of life indicators could improve by 10% to 30% based on different levels of adoption of Smart City solutions, depending on the level of maturity. This estimate is based on previous case studies and research reports.[1]



It is believed, for example, that already the current generation of smart city applications would help to make significant progress towards achieving 70 per cent of the Sustainable Development Cities targets.

The benefits identified by McKinsey[2] are classified into 7 areas:

Security

Improved security in smart cities involves the use of various applications and data to enhance emergency response times, surveillance and reduce crime rates. By utilizing such technologies intensively, it is estimated that there could be an 8-10% reduction in homicide, road traffic and fire fatalities, which is

[1] *McKinsey Global Institute Smart Cities: digital solutions for a more livable future - June 2018*
[2] *McKinsey Global Institute Smart Cities: digital solutions for a more livable future - June 2018*

equivalent to saving about 300 lives each year in a city the size of Rio de Janeiro, Brazil. Furthermore, incidents of assault, robbery and burglary could also decrease by 30-40%.

Additionally, optimized dispatching and synchronized traffic lights could potentially reduce emergency response times by 20-35%.

Better time management in urban mobility

The use of tools for governing traffic, road maintenance, and various transport systems, as well as applications and data available to citizens to make their daily commute less complicated and stressful. It aims to reduce the time lost in traffic congestion, especially in large cities, and is crucial to improving the quality of life.

By 2025, cities that implement smart mobility applications could reduce travel time by an average of 15 to 20 percent, with workers gaining 20 to 30 minutes every day.

The applications are numerous, and include the use of digital signage, intelligent synchronization of traffic lights, or mobile apps to provide real-time information on public transport delays or estimated travel times to allow citizens to adapt their routes on the fly, Internet of Things (IoT) sensors on infrastructure to predict road maintenance needs, use of faster and integrated payment systems (public transport, taxis, ride sharing), and indications of available parking spaces.

Health

The advancements in healthcare technology present cities with unique and effective areas for application, particularly due to their density and size.

By maximizing the use of these applications, the Disability-Adjusted Life-Year (DALY), a metric for measuring the health burden, encompassing both reduced life expectancy and diminished quality of life (i.e., years of life lost or "not lived" due to illness), can be reduced by 8-15%, depending on each locality's starting point and underlying public health challenges.

Remote patient monitoring for chronic disease treatment can reduce healthcare burden in high-income cities by more than 4%. Targeted interventions based on maternal and child health data and analysis can also decrease DALY rates by 5%.

Furthermore, an additional 5% reduction can be achieved through the utilization of surveillance systems for infectious diseases and rapidly spreading epidemics.

Telemedicine offers new methods for interacting with patients, such as providing clinical consultations via videoconferencing, which can improve access to care in low-income cities facing a shortage of doctors.

Environment, healthier and more sustainable

The use of technology can help to reduce the environmental impact of increasing urbanization, industrialization, and consumption levels in cities. The implementation of a range of applications could reduce emissions by 10-15%, decrease water consumption by 20-30%, and lower the volume of solid waste per capita by 10-20%.

Commercial building automation systems can reduce emissions by just under 3%, and if applied in residential buildings, there could be an additional 3% reduction. Smart energy pricing could shift consumption to off-peak hours, reducing the polluting impact. Applications that improve mobility, reduce traffic congestion, and improve vehicle transit would significantly reduce emissions, thereby improving air quality. Sharing real-time information on air quality with the public would allow protective measures to be taken, potentially reducing negative health effects by 3-15%, depending on current pollution levels.

Regarding water, 25 to 80 liters less water could be consumed per day. Monitoring consumption can encourage savings, reducing consumption by 15%. Implementing sensors and analyzing the distribution network can also reduce losses by up to 25%.

Regarding waste reduction, technology could be used to further reduce the volume of unrecycled solid waste. For example, digital monitoring and payment for waste disposal based on the exact amount and type of waste thrown away could reduce waste by 30 to 150 kg.

Social cohesion

A survey conducted by McKinsey has shown that the use of digital platforms or applications can increase the proportion of residents who feel connected to their local community by double and triple the proportion who feel connected to local government, respectively.

Communication channels can be established between citizens and city administrations to report problems, collect data, or evaluate planning issues. They can also help build connections between neighbors, mobilize action on specific issues, and provide support during emergencies.

Positive impact on employment

Although technology may lead to the direct elimination of some jobs, such as administrative and operational roles in city government, it can also create new ones, such as maintenance positions, vehicle driving jobs, and roles associated with temporary construction sites. New professional figures will have to emerge for the management of digital platforms and data analysis.

The digitization of public administration processes, such as business licenses, permits, and tax returns, can reduce bureaucracy and enhance the business climate for local enterprises.

Furthermore, a variety of smart city technologies could have a slightly positive net impact on employment, potentially increasing it by 1-3% by 2025.

Cost of living

Smart city applications can offer benefits not only in terms of improving the quality of life but also in terms of creating savings of up to 3% on current annual expenses.

For instance, better management of land and building areas can lead to lower house prices and living in healthier or less polluted environments can lead to savings in healthcare costs.

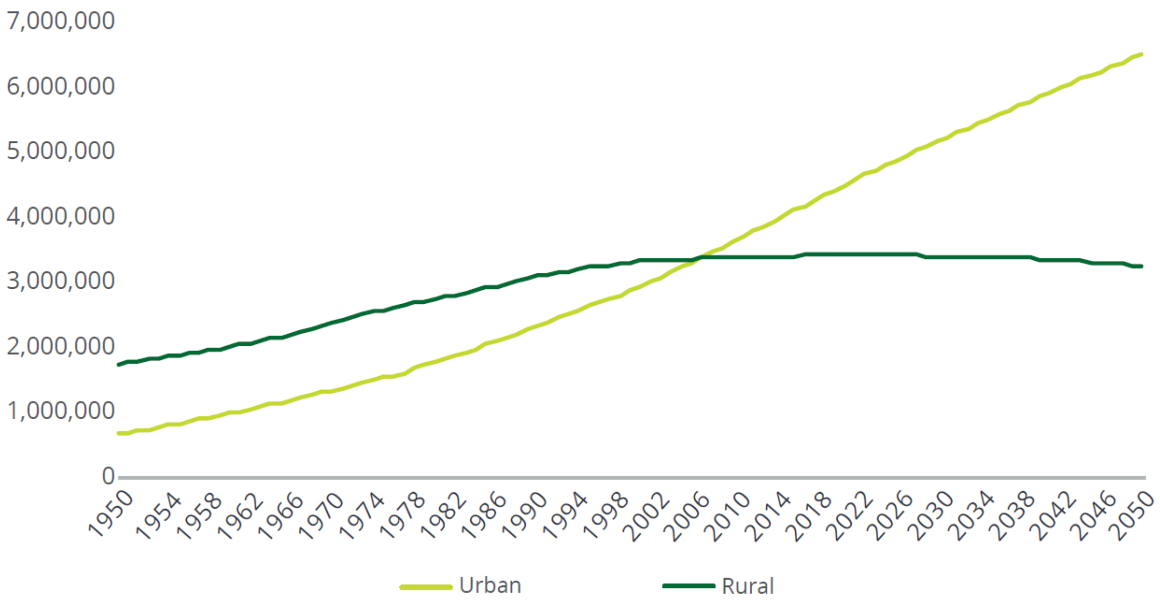
Furthermore, mobility applications, such as e-hailing and sharing applications, can contribute to cost savings by enabling people to avoid private vehicle ownership.

The main scenario elements promoting the development of Smart Cities

The majority of the world's population lives in urban areas, with 56% residing in cities as of 2021[3], and this percentage continues to rise.

The anticipated growth of the global population (which, despite recent predictions of a slowdown, could still reach 9.7 billion individuals by 2050[4]) and the gradual shift of people from rural areas to areas with greater employment and opportunities will result in an increase of approximately 2.5 billion individuals in urban populations, primarily in Asia and Africa[5]. By 2050, the urban population is expected to make up 66% of the world's population[6].

Urban and Rural Population in the World [7]



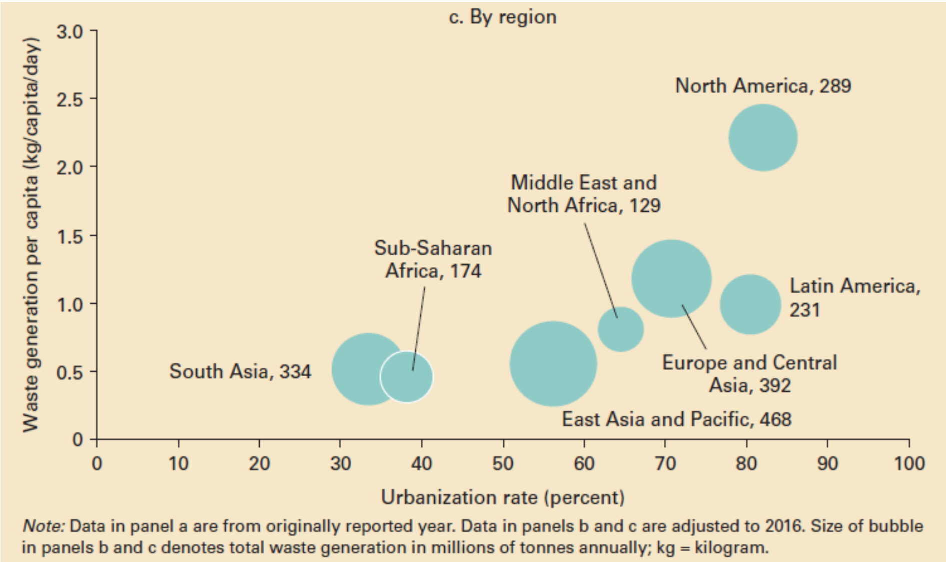
[3] *The World Bank's 2021 Update on European Nation - 2018 Revision of World Urbanization Prospect*
[4] *2022 Revision of World Population Prospects https://www.un.org/development/desa/pd/sites/ www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf*
[5] *European Nation – 2018 Revision of World Urbanization Prospect*
[6] *Projection United Nation - World Urbanization Prospects*
[7] *Projection United Nation - World Urbanization Prospects*

Cities have a major impact on the environment

Rapid urban growth presents both an opportunity and a challenge for the implementation of an ambitious urban development agenda that aims to create inclusive, safe, resilient, and sustainable cities and human settlements.

In terms of their impact on the environment, cities are responsible for:

- **for producing over 75% of global waste.**
  Waste generation increases with urbanization, and high-income countries and economies that are more urbanized produce more waste per capita and in total. North America has the highest urbanization rate of 82%, generating 2.21 kilograms per capita per day, while sub-Saharan Africa has the lowest rate of 0.46 kilograms[8] per capita per day.



- **generating approximately 80% of greenhouse gas emissions.**
  The projected population growth, coupled with the resulting increase in urban sprawl (which already expands at twice the rate of urban population growth, on average), could further amplify the global contribution of cities to emissions. Unless deliberate policy interventions are implemented to control urban sprawl[9], the situation is likely to deteriorate.

- **75% of energy consumption**
  Urban areas currently host 55% of the world's population and consume almost 75% of the global primary energy supply[10]. Estimates indicate that by 2050, the urban

[8] *Worldbank 2018 - What a Waste 2.0 A Global Snapshot of Solid Waste Management to 2050*
[9] *IPCC Special Report on global warming*
[10] *United Nations 2016*

population is expected to account for nearly 70% of the world's population, which could increase urban energy demand beyond its current level.

UN Sustainable Development Goal No. 11 concerns Smart Cities

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations (UN) in 2015 as a universal call to action with 17 goals to end poverty, protect the planet[11], and ensure that all people enjoy peace and prosperity by 2030.

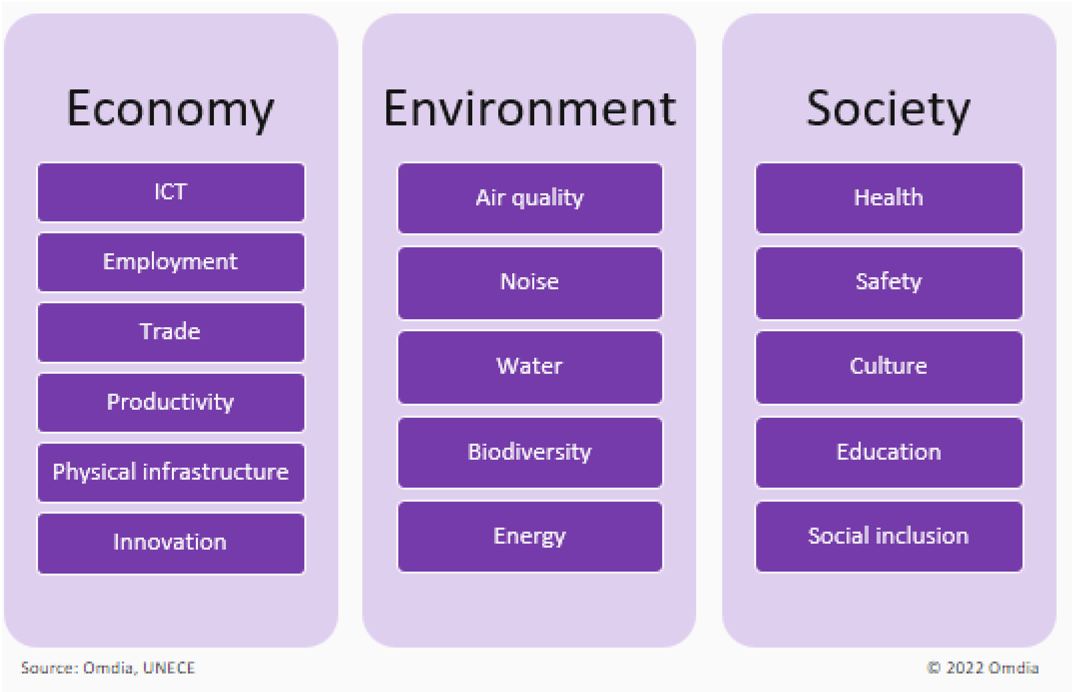
Sustainable Development Goal SDG 11 is dedicated to cities, which are to be made safer, more resilient, inclusive, and sustainable.

The evolution towards Smart Cities in urban environments is, therefore, not only a necessity but also a global objective. It is no coincidence that the United Nations Economic Commission for Europe (UNECE) defines a smart and sustainable city as "an innovative city that uses ICT and other means to improve the quality of life, the efficiency of urban operations and services, and competitiveness while ensuring that it meets the needs of present and future generations with regard to economic, social, environmental, and cultural aspects'[12].

To monitor progress towards achieving the Sustainable Development Goals (SDGs), the International Telecommunication Union (ITU), in collaboration with other UN organizations, has developed a set of Key Performance Indicators (KPIs) for smart and sustainable cities. These KPIs comprise 92 indicators (both core and advanced) covering the three dimensions of sustainable development: economic, environmental, and socio-cultural. The KPIs address themes such as ICT, transport, productivity, infrastructure, spatial planning, innovation, air quality, water and sanitation, waste, public space, energy, education, health, culture, security, housing, food, and social inclusion.

[11] *2030 Agenda for Sustainable Development Goal*
[12] *https://unece.org/housing/sustainable-smart-cities*

KPIs for assessing sustainable Smart Cities[13]



Public Funding

Public funding for sustainable urban development is on the rise.

The European Union (EU) allocated over 85 billion euros from 2014 to 2020 through the Horizon 2020 program. In the new Horizon Europe project (100 billion euro 2021-2027), a significant portion of the expenditure is dedicated to Smart Cities. In fact, Climate Neutral & Smart City is one of the five Mission Areas, with the goal of supporting, promoting, and showcasing 100 European cities in their systemic transformation towards climate neutrality by 2030 and transforming these cities into innovation hubs for the benefit of quality of life and sustainability in Europe[14].

Another crucial factor is the integration of public and private organizations, which must be oriented towards the same goal. A smart city is a place that knows how to integrate all its resources, regardless of their origin. With this in mind, the **Smart Cities Marketplace** is one of the main platforms at the European level that aims to bring together projects related to the development of smart cities with industries, SMEs, investors, researchers, and other stakeholders. To date, the Smart Cities Marketplace has mobilized 616.3 million euros out of 127 eligible proposals received, involving 17 investor networks.

[13] *Omdia, Internet of Things as an Enabler for Sustainable Smart Cities*, 2022
[14] *https://ec.europa.eu/info/horizon-europe/missions-horizon-europe/climate-neutral-and-smart-cities_en*

According to the European Commission portal, the total number of projects received is 227[15], while Spain has submitted the most projects to date (35), followed by Sweden and Italy (tied with 18), the Netherlands (17), and Germany and France (16 each).

As part of these programs, there is also the NextGenerationEU, a funding plan of 750 billion euros (of which 672.5 billion euros is made available by the Recovery and Resilience Fund) designed by European Union to counter the economic and social effects of the coronavirus pandemic and to make the post-COVID-19 European Union greener, more digital, resilient, and able to face current and future challenges.

In this regard, all Member States have submitted to the European Commission a plan of actions and reforms to be financed in compliance with the constraints required by Europe: at least 20% of the funds allocated to digital and 37% to climate transition measures.

The planned interventions, designed to reap the benefits of green and digital transitions, are divided into the four dimensions: Environmental sustainability, Productivity, Equity, and Macroeconomic stability.

Examples of reforms and investments proposed by the Commission include:

- efforts to structure and coordinate actions aimed at making urban mobility cleaner, smarter, safer, and more equitable, in line with the sustainable mobility strategy.
- measures to improve energy efficiency, building and housing renovation, climate, social, resource efficiency, and circular economy policies.

These examples of investment proposed by Europe, together with the general objective of digital transition, can open up further investment spaces for local governments in the development of Smart Cities, as a set of applications aimed precisely at improving living conditions, sustainable mobility, a circular economy, and the environmental improvement of cities.

These examples of investments proposed by European Union, combined with the general objective of digital transition, can create additional opportunities for local governments to invest in the development of Smart Cities, which consist of a set of applications aimed at improving living conditions, sustainable mobility, circular economy, and environmental conditions in cities.

The National Recovery and Resilience Plan (NRRP) and Smart Cities

To promote social inclusion in Italy by reducing marginalization and situations of social decay, facilitate urban regeneration through eco-sustainable recovery, renovation, and

[15] *https://smart-cities-marketplace.ec.europa.eu/, data as at 23 February 2023*

repurposing of building structures and public areas, and support projects related to Smart Cities, particularly in transport and energy consumption, the Decree-Law of 6 November 2021 allocated over 10 billion euros to Smart City projects for the period 2022-2026. Of this, almost 2.5 billion euros have been allocated to metropolitan cities as part of the National Recovery and Resilience Plan (PNRR), in implementation of the project line 'Integrated Plans - M5C2 - Investment 2.2'.

The Decree of the Ministry of the Interior of 6 December 2021 approved the model by which interested Metropolitan Cities can identify the interventions that can be financed, within the maximum limit of the resources allocated by Annex 1 of Article 21, paragraph 3 of Law Decree no. 152/2021. To implement these plans, "participatory urban planning is envisaged, with the aim of transforming vulnerable territories into smart and sustainable cities, limiting the consumption of building land".

The objectives are diverse: to restructure the urban and suburban fabric, bridging infrastructural and mobility deficits; to revitalize urban spaces and existing areas to improve the quality of life; and to promote social and entrepreneurial participation processes. The projects will also need to restore communities' identity by promoting social, cultural, and economic activities.

The largest share of the resources (allocated based on the resident population and social and material vulnerability, measured through a special index) goes to the metropolitan city of Naples (351 million euros), followed by the capital Rome (330 million euros), Milan (277 million euros), Turin (234 million euros), Palermo (196 million euros), Catania (186 million euros), Bari (182 million euros), Florence (157 million euros), Bologna (157 million euros), Genoa (141 million euros), Venice (140 million euros), Messina (132 million euros), Reggio Calabria (119 million euros), and Cagliari (101 million euros).

Funded projects will focus on investments aimed at improving large deprived urban areas for regeneration and economic revitalization, with a focus on the creation of new personal services and the upgrading of accessibility and infrastructure.

These interventions will enable the transformation of vulnerable territories into smart and sustainable cities, through:

a) Maintenance for environmentally sustainable reuse and repurposing of existing public areas and building structures for public interest purposes.

b) Improving the quality of urban aesthetics and the social and environmental fabric, including the renovation of public buildings, with a particular focus on developing and enhancing social and cultural services and promoting cultural and sports activities.

c) Interventions that support Smart City projects, especially in transport and energy use, to enhance the environmental quality and digital profile of urban areas by promoting digital and low-carbon technologies.

The Metropolitan Cities submitted their proposals by 7 March 2022 exclusively for interventions worth no less than 50 million euros. By the decree of 22 April 2022, the Ministry of Finance, in agreement with the Ministry of the Interior, published the list of metropolitan city projects eligible for funding with PNRR funds and complementary funds.

Below is the list.

Integrated Urban Plans Eligible for Funding[16]

Metropolitan City	Integrated Urban Plan (PUI)	Number of inhabitants in the intervention area	Savings in energy consumption (MWh/year)	Amount PUI[17] ('000 €)	Amount of co-financing ('000 €)	Total Integrated Plan ('000 €)
BARI	"IDENTITÀ È COMUNITÀ"	587.939	4.749	112.419	890	113.310
	"VERDE METROPOLITANO" LANDSCAPE / FORESTATION / ENVIRONMENTAL EDUCATION / QUALITY OF LIFE / CARBON LOW	270.126	566	69.548	616	70.164
	Total PUI BARI	**858.065**	**5.315**	**181.967**	**1.506**	**183.473**
BOLOGNA	METROPOLITAN NETWORK FOR KNOWLEDGE. LA GRANDE BOLOGNA	**479.693**	**170.456**	**157.338**	**15.731**	**173.068**
CAGLIARI	SUSTAINABLE RING INTEGRATED URBAN PLAN OF THE METROPOLITAN CITY OF CAGLIARI	**419.959**	**641**	**101.228**	**4.028**	**105.256**
CATANIA	RECOVERY AND REDEVELOPMENT OF DEGRADED AREAS IN THE MUNICIPALITIES OF CALATINO	134.386	1.832	51.478	-	51.478
	CTA, A SYNTHESIS OF URBAN MARGINS	359.000	250.000	134.009	-	134.009
	Total PUI CATANIA	**493.386**	**251.832**	**185.487**	**-**	**185.487**
FLORENCE	SPORT AND WELLNESS - NEXT RE_GENERATION FLORENCE 2026	209.013	1.893	71.609	102.773	174.382
	NEXT RE_GENERATION FLORENCE 2026-PROPOSAL 2: CULTURE AND SOCIAL INCLUSION	210.931	763	85.627	10.258	95.885
	Total PUI FLORENCE	**419.944**	**2.656**	**157.236**	**113.031**	**270.266**
GENOA	FROM PERIPHERIES TO NEW URBAN CENTRALITIES: SOCIAL INCLUSION IN THE METROPOLITAN CITY OF GENOA	**198.260**	**867**	**141.208**	**-**	**141.208**

[16] *Decreto Interministeriale del 22 aprile 2022 del Ministero delle Finanze, di concerto con il Ministero dell'Interno, e Decreto del Ministero dell'Interno del 21 dicembre 2022 - Rettifica Allegato n.2 "Dettaglio PUI" al Decreto Interministeriale del 22 aprile 2022.*

[17] *art. 21 del D.L. 152/2021, convertito con modificazioni dalla legge n. 233 del 2021*

Metropolitan City	Integrated Urban Plan (PUI)	Number of inhabitants in the intervention area	Savings in energy consumption (MWh/year)	Amount PUI[18] ('000 €)	Amount of co-financing ('000 €)	Total Integrated Plan ('000 €)
MESSINA	CITTA' DEL RAGAZZO	8.500	1.000	55.660	-	55.660
	EXTENSIVE AREAS OF ENVIRONMENTAL, CULTURAL AND SOCIAL-TOURIST VALUE	50.000	1.392	76.493	-	76.493
	Total PUI MESSINA	**58.500**	**2.392**	**132.153**	**-**	**132.153**
MILAN	AS IN - INCLUSION SPACES AND SERVICES FOR METROPOLITAN COMMUNITIES	709.548	6.741	66.114	10.045	76.159
	METROPOLITAN CITTÀ SPUGNA - A 'città spugna – city sponge' refers to a particular type of urban planning, which chooses Nature Based interventions as the most effective means of reducing flooding, conserving water for times of drought and reducing water pollution.	814.127	126	50.194	-	50.194
	CHANGE: 70 KILOMETRES OF SUPER-CYCLES WITHIN THE METROPOLITAN CITY OF MILAN	553.738	4.861	50.068	-	50.068
	MICA - INTEGRATED, CONNECTED AND ACCESSIBLE MILAN	1.352.000	635.941	110.917	-	110.917
	Total PUI MILAN	**3.429.413**	**647.669**	**277.293**	**10.045**	**287.338**
NAPLES	"RESTART SCAMPIA_A NEW ECO-NEIGHBOURHOOD IN THE AREA OF THE FORMER LOTTO M".	1.000	4.622	70.000	-	70.000
	REDEVELOPMENT OF THE TAVERNA DEL FERRO SETTLEMENT	1.300	2.582	52.000	-	52.000
	A RENEWED IDEA OF RESILIENT LIVING IN THE PHLEGRAEAN FIELDS AND GIUGLIANESE AREA: A WIDESPREAD REGENERATION PLAN	352.327	573	52.510	-	52.510
	SMART CITY NAPLES NORTH: A NEW SUSTAINABLE MOBILITY	439.430	6.412	52.952	-	52.952
	A NEW SYSTEM FOR SPORT AND SOCIAL INCLUSION FOR THE VESUVIO-NOLANA INLAND AREA	189.413	826	52.717	-	52.717
	A RENEWED RELATIONSHIP WITH THE SEA: SYNERGIES AND SUSTAINABLE NETWORKS BETWEEN INLAND AREAS AND COASTAL MUNICIPALITIES	556.246	878	70.972	-	70.972
	Total PUI NAPLES	**1.539.716**	**15.893**	**351.151**	**-**	**351.151**
PALERMO	"PALERMO: OPEN METROPOLIS, CITY FOR ALL'.	**1.027.590**	**42.521**	**196.177**	**1.954**	**198.131**

[18] *art. 21 del D.L. 152/2021, convertito con modificazioni dalla legge n. 233 del 2021*

Metropolitan City	Title Integrated Urban Plan (PUI)	Number of inhabitants in the intervention area	Savings in energy consumption (MWh/year)	Amount PUI[19] ('000 €)	Amount of co-financing ('000 €)	Total Integrated Plan ('000 €)
REGGIO CALABRIA	ASPROMONTE IN CITTÀ A GREEN, SUSTAINABLE, INCLUSIVE AND SMART METROPOLITAN CITY	**471.125**	**13.336**	**118.596**	**-**	**118.596**
ROME	CORVIALE SOLIDARITY POLE	15.870	1.806	50.044	-	50.044
	CULTURAL, CIVIC AND INNOVATION POLES	846.290	7.213	90.975	-	90.975
	SANTA MARIA DELLA PIETÀ WELLNESS CENTRE	316.777	1.588	50.082	-	50.082
	POLES OF SPORT, WELL-BEING AND DISABILITY	284.245	58	59.337	-	59.337
	SUSTAINABILITY POLE - MOBILITY AND ENERGY - TOR BELLA MONACA	106.491	3.717	79.874	-	79.874
	Total PUI ROME	**1.569.673**	**14.382**	**330.312**	**-**	**330.312**
TURIN	"TORINO METROPOLI AUMENTATA': INHABITING THE TERRITORY	732.571	22.010	120.553	29.277	149.830
	PIÙ - INTEGRATED URBAN PLAN OF THE CITY OF TURIN	861.636	699	113.395	-	113.395
	Total PUI TORINO	**1.594.207**	**22.709**	**233.948**	**29.277**	**263.225**
VENICE	MORE SPRINT (INTEGRATED URBAN PLAN FOR SPORT REGENERATION INCLUSION IN THE VENETIAN METROPOLITAN AREA)	**695.494**	**1.954**	**139.637**	**194.155**	**333.793**

The total funding amounts to 2,722,306,571 euros for 31 projects, out of which 2,352,579,932 euros was allocated from PNRR resources.

The project proposals submitted included:

a) The potential for private participation through the ' Fondo Ripresa Resilienza Italia - Resilience Italy Fund' of up to a maximum of 25% of the total intervention cost;

b) The optional inclusion of public service start-ups in the project proposal;

c) Collaborative planning with the third sector.

How a Smart City is built

The concept of a Smart City and its interconnected components have been gaining recognition as valuable for urban development. To be considered a "smart" city, it must have an inter-functional structure that is data-driven, based on data management and

[19] *Article 21 of Decree-Law No. 152/2021, converted with amendments by Law No. 233 of 2021*

analysis. This requires an information technology architecture that can collect data from various sensors, interpret it with analytics, and increase knowledge of different phenomena.

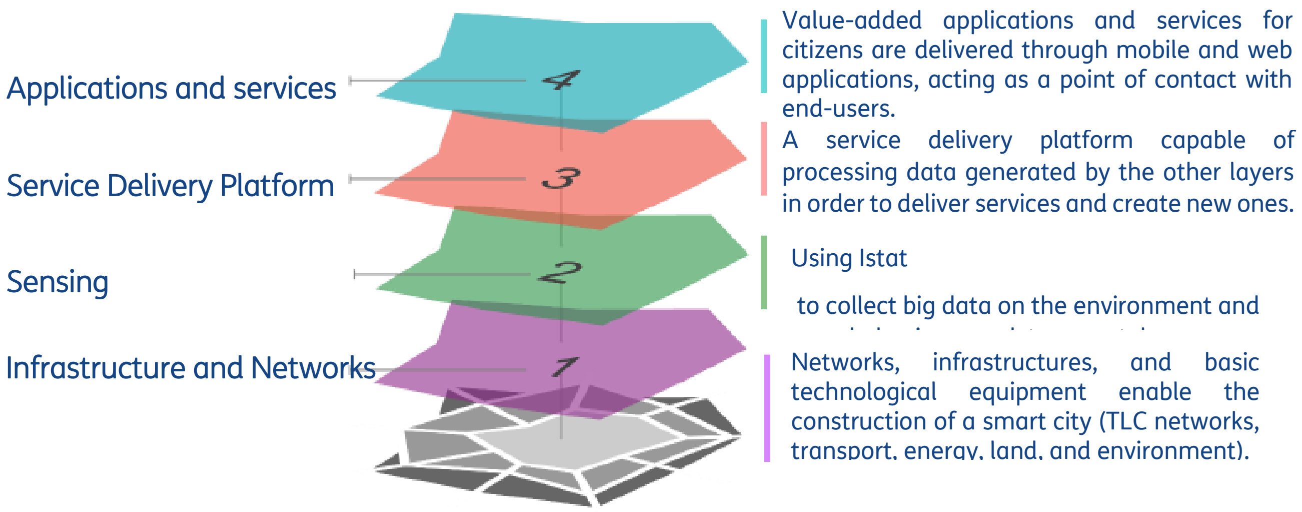
The architecture of a Smart City can be exemplified by several layers, as outlined by EY[20] methodology. These include:

- 4 integrated layers (Infrastructure and Networks, Sensing, Service Delivery Platform, Applications and Services), through which the Smart City is designed and implemented.
- 2 additional areas, which relate to the city's ability to provide a strategic vision and planning framework for the path towards the Smart City (Vision and Strategy), and the quality of life resulting from the use and perception of smart services by citizens (Smart citizen and livability of the city).

This layered structure provides a comprehensive view of the broad, complex, and ever-changing phenomenon of urban smartness, encompassing multiple areas such as mobility, energy, public administration, and health.

In this paper, we do not intend to utilize the indicators underlying each stratum or domain, which EY uses to evaluate and rank Smart Cities, but instead, we aim to illustrate the four strata as an example of the technological and digital structure that forms the foundation of a Smart City.

The 4 architectural layers of the Smart City[21]



[20] *Booklet Smart City – Milano nel contesto europeo, n. 3/2020, a cura di Centro Studi Assolombarda – EY*
[21] *Booklet Smart City - Milano nel contesto europeo, no. 3/2020, edited by Centro Studi Assolombarda - EY*

1. Infrastructure and Networks

The first layer represents the foundation upon which all services and activities of the Smart City are based. It comprises networks, infrastructures, and enabling technology for building a smart city, such as transport, telecommunications, and energy. This includes 5G, Wi-Fi, and Li-Fi connections, broadband and ultra-wideband for telecommunications, as well as the availability of cloud and distributed network architectures. Also included are car parks with charging facilities for electric vehicles and service infrastructures such as water, gas, and electricity.

2. Sensing

This second layer pertains to the sensor networks and IoT devices necessary for collecting and analysing big data related to the environment (air, water, etc.), user behaviour, and infrastructure condition for remote management and maintenance. This layer involves sensors that are useful for smart metering, underground utility control, sharing mobility vehicle localisation, transponders for optimising public transport, waste management, and green area management. For instance, sensors can detect building security, be integrated into LED street lighting, and monitor environmental control, road networks and traffic, and mobility.

3. Service Delivery Platform

The service delivery platform needs to be capable of processing and utilising the vast amounts of big data generated by the other layers to enhance current services and develop new ones. It must function as an operations center that can interface with information flows from various sources, aggregate them, and derive new insights. For instance, it can extract data from a single source like a video camera and employ it for different purposes like security, traffic management, or smart parking.

4. Applications and services

The fourth and final layer focuses on creating value-added services for citizens through mobile and web applications, which serve as the primary point of contact with end-users. This layer includes all aspects related to health, tourism, mobility, and government services, such as identification systems. It must integrate and engage with the other three layers to provide citizens with valuable and useful services that improve their quality of life.

The process of building a Smart City should focus on establishing an interconnected foundational infrastructure and a unified service delivery platform that can process data from sensors and provide value-added services to citizens, thereby enhancing their quality of life.

Telecommunications and Smart City technologies

So far, we have described the need for Smart Cities to monitor and analyze the urban environment with appropriate sensors and devices. In reality, every smartphone in use within a city can become a sensor, capable of providing information on the movement patterns of its inhabitants.

This means that millions of sensors will be able to upload data from streets, buildings, and IoT devices to the cloud for analysis to optimize city management. This will make it possible to generate a digital picture of the city ecosystem as long as all data sources are well interconnected. Self-driving cars also need an intelligent city ecosystem because, in reality, they are not fully autonomous. In fact, they rely on the existence of a permanent, unlimited, and almost real-time data exchange system with roads, infrastructure, other road users, and the surrounding environment. This process generates many terabytes of data every day that must be transmitted and collected via telecommunications networks between sensors.

So, what are the Machine-to-machine (M2M) communication technologies on which the construction of a Smart City is based?

LPWA Network

For the construction of IoT sensor networks, there are various wireless alternatives that belong to the family of Low Power Wide Area (LPWA) Networks. These data transmission technologies have a high device density, low costs, wide coverage, and low power consumption, which can allow batteries not powered by the mains to last for decades.

The choice of networking technology is often left to the city administration or the public utility responsible for managing most of the city's essential services.

As there is no single solution for all types of needs or applications, the choice of networking technology is wide. Navigant Research, a research company, has evaluated different wireless technologies for each of the main functions that may be required in a Smart City.

The technologies considered are:

SigFox: is a technology in which communication is one-way, not bidirectional, and the data transfer rate is very low. It is well-suited to scenarios where sensors have to communicate a limited amount of data sporadically, where latency is not a critical factor. However, the inability to send data to devices can be a limiting factor in some areas of use, such as cases where the firmware of on-the-air devices needs to be updated.

LoRaWAN: is a proprietary long-range wireless communication protocol that is widely used in IoT applications in Smart Cities. It was developed to facilitate low-frequency data transmission over long distances between sensors and actuators in the IoT. LoRaWAN operates outside the LTE (Long Term Evolution) spectrum associated with the 4G and 5G wireless communications standard and typically offers higher average latencies than the aforementioned technologies, but it boasts even lower power consumption. In fact, a device can be powered for up to 15 years by the same battery, resulting in a lower TCO (Total Cost of Ownership). It is highly valued in the utility sector, such as gas and water, where latency is not critical.

NB-IoT or Narrowband IoT: is a versatile connectivity technology based on 4G LTE and is a 3GPP standard, common to all mobile telecommunications operators. It is particularly suitable for ensuring IoT connectivity in applications that do not involve continuous transmission or reception of information, making it ideal for closed environments like factories or smart buildings. Its strength lies in its high device density, supporting up to 50,000 devices per single cell. By using only a limited portion of the radio spectrum, NB-IoT keeps power consumption low, with a single battery capable of powering a device for up to 10 years. In Italy, it provides coverage across the entire country.

Connection Technologies and Wireless Sensor Networks for Smart Cities[22]

TECHNOLOGY	LIGHT CONTROL	ENVIRONMENTAL MONITORING	TRAFFIC MONITORING	SMART PARKING	TRAFFIC LIGHT CONTROL
SigFox	****	***	**	**	*
LoRaWAN	****	****	***	**	*
NB-IoT	****	****	***	**	**
3G-4G	**	**	**	**	**
5G	****	****	****	****	****

*** = unsuitable **=unsuitable ***= acceptable ****= suitable**

Wireless MBus 169 MHz

The Wireless M-Bus, or Wireless Meter Bus (wM-Bus), is a European EN 13757 open standard developed for highly power-efficient smart metering[23] and Advanced Metering Infrastructure (AMI) applications. It comprises several operating modes: S, T, R, and C (868 MHz), F (433 MHz), and N (169 MHz). The protocol is gaining popularity in Europe for its use in electricity, gas, water, and heat metering. At the application level, the protocol provides two types of communication mechanisms: Access Timing, in which the meter wakes up at

[22] *Processing Centro Studi TIM on Navigant Research data*
[23] *European Committee for Standardisation, 'EN 13757-4,' 2011.*

set times to communicate reading data to the concentrator, and Synchronous Transmission.[24], in which the meter is notified of commands directed to it upon waking up and establishes a dialogue with the concentrator.

According to ARERA's indications[25], it is a preferred protocol for collecting information from gas meters and can also be used as a multi-service network, in combination with 868 MHz transmission, the latter often used for monitoring water and heat meters. The protocol is suitable for data exchange with low bandwidth requirements, and the low operating frequency should allow for greater distances to be reached and be less affected by obstacle attenuation, although its use in urban areas has been verified to reach distances 2-3 times shorter than in suburban areas under the same conditions.

The concentration factor and the number of devices that can be reached, including meters, sensors, and others, make it possible to optimize radio coverage, thus enabling the network's deployment costs and revenues to be predicted during the business planning phase.

5G technology

The 5G cellular telephony standard increases the speed of data flow between vehicles, smartphones, machines, data centers, buildings, sensors, devices and controls by a factor of 50-100 for every possible Smart City-related use, compared with the currently installed 4G LTE technology.

5G can provide virtually real-time responses with very low latency and can utilize bands at various frequencies, even higher than other technologies, with a simultaneous increase in efficiency.

The prerequisites for all of this are: first, the creation of small cells in numbers around ten times greater than those required for current radio coverage; and second, the establishment of fiber optic links between all these new antennas and the existing network. The network will also need to expand, again in optical technology, to manage the massive flow of data generated by smart cities and their growing population.

Optical Fiber

A crucial aspect that is often overlooked when discussing Smart Cities is physical connectivity, i.e., the cabling between antenna sites, central switching stations, and also data centers above and below the ground. Cables are the foundation of the Smart City.

Smart technologies cannot distribute data if they are not networked. Although it is true that the connections between the end-user and the network are partly realized with

[24] *Notiziario Tecnico Telecom Italia, No. 3/2013, Dallo Smart Metering alla Smart Urban Infrastructure.*
[25] *https://www.arera.it/it/operatori/smartmetering.htm*

wireless technology, robust, modern fiber-optic cabling must be implemented between the receiving antenna and the network.

The information service TechTarget writes: "probably the most important challenge for Smart Cities is the complexity of connectivity." And the McKinsey Global Institute adds: "before a city can call itself smart, it must be wired." 5G base stations and mini radio cells must also be integrated into the network using fiber optic technology. A study by consultants Deloitte concludes that "fiber optics are the lifeblood of 5G".

The Journal of Internet Services and Application confirms: "When a Smart City application is used universally, it generates a huge volume of data traffic that can lead to serious performance problems for the underlying network infrastructure." Network architectures for Smart Cities demand an open planning concept because data traffic is set to continue its dynamic growth for decades to come.

A natively interoperable network infrastructure

Wireless and wired networks cannot be dimensioned independently anymore. Fiber-to-the-Antenna (FTTA) and Fiber-to-the-Home (FTTH) networks will develop in conjunction in the future. The creation of a Universal Fiber Grid (UFG) that can support all potential applications is the ideal solution for planning. Separate lines for individual functions will soon be outdated. The traditional approach to adding lines to the infrastructure of a city is not only inconvenient but requires multiple digs of the same area, which can be avoided with a network approach from the beginning. Coordination between the public administration and infrastructure providers is essential in planning the creation of a Smart City.

The Smart City plan must include a densely interconnected fiber optic communication and data transport network, and the replacement of all obsolete networks. The network plan must cover a time span of 20 to 30 years, and it is as important as infrastructure planning for water, sewage, electricity, and gas.

A correctly dimensioned, uniform, and scalable fiber-optic infrastructure is the only solution for continuous performance at the network level. It must be able to grow in parallel with the city and its needs, handling the full-field and virtually real-time data traffic between mobile terminal devices, vehicles, the entire field of IoT applications, and network subscribers.

Compact mini data centers at the periphery of networks (edge data centers) are indispensable for the development of time-sensitive applications, such as remotely controlled surgeries or autonomous driving of vehicles in cities. Interactions between terminal devices and the network cannot last longer than a few nanoseconds, and data must be processed practically in real-time with respect to the action that generated it and with low latency. A near-instantaneous flow of information is indispensable, and this type of data center, with redundant fiber-optic connections, should be available every 5-15 km.

Smart City applications

In practice, the Smart City concept is realized through a set of applications and systems that are available to citizens, businesses, and the administration to achieve the promised benefits of this new model for developing and managing city life. With increasing urbanization of the population, the urgent need to limit environmental impact, and to provide citizens with not only an adequate, but also a sustainable and healthy standard of living, numerous applications, experiments, and implementations of systems similar to the Smart City concept are rapidly spreading worldwide.

The various Smart City applications can be classified into Smart 'Scopes' based on their characteristics and the type of benefits they generate. Various ontologies have been proposed in the literature or in the numerous studies that attempt to explain and trace the evolutionary trajectories of Smart Cities.

Below is the one from the European Smart City Project[26], which categorizes the applications into six groups:

Smart Living and Smart People

In these two areas, which are reported here together, there are applications that enable citizens to experience their everyday life and the context of relationships offered by the city in a new, more effective, and accessible way. Smart People also include the e-skills needed to use digital services, ICT-enabled work (such as the currently popular smart working), access to education and training, and the management of skills within an inclusive society that enhances creativity and promotes innovation.

In the field of health, **Smart Health** (or e-health) solutions allow people to use health services, monitor their own health status, or receive appropriate tips and advice for healthy living.

In the cultural sphere, **Smart Culture** applications facilitate access to services and cultural and educational heritage, cultural mediation, propose new models of fruition with the creation of digital experiences, and involve the active participation of citizens who can also become protagonists.

A fundamental field of applications concerns **Smart Buildings**, i.e., solutions that increase the quality of living while also reducing the environmental impact of buildings in terms of resources consumed, waste produced, and greenhouse gas generation. Due to the importance that buildings can have in

[26] *http://www.smart-cities.eu/ and Mapping Smart Cities in EU https://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/507480/IPOL-ITRE_ET(2014)507480_EN.pdf*

achieving sustainability goals, Smart Building applications are often associated with the Smart Environment cluster.

Smart Economy

Smart Economy refers to a range of e-business and e-commerce activities and technologies that are implemented within cities to enhance productivity, provide advanced production services, and foster innovation enabled by telecommunications infrastructure. It includes the development of new products, services, and business models. Moreover, Smart Economy involves the integration of local and global interconnections and international ties through the physical and virtual exchange of goods, services, and knowledge.

Smart Governance

Smart Governance aims to improve the efficiency and transparency of city administration through the use of ICT infrastructures, intelligent processes, and collected data. These applications enable the management and control of the city, connecting and integrating public, private, and civil organizations to function as a single body. Partnerships and collaboration with different stakeholders are important in achieving smart city-wide goals.

Open data access and availability are also essential in smart governance to increase citizen participation in the city's decision-making processes. Services such as digital counters for dialogue with the municipality or administrative services, reporting apps to notify inefficiencies or maintenance needs, and notifications to citizens for the bulky waste collection calendar are examples of initiatives to involve citizens.

Smart Mobility

Smart Mobility refers to the intelligent management and use of transport systems, optimized and sustainable mobility of people and goods, integrated and supported by ICT. The concept of Smart Mobility includes personal safety, allowing for safe travel in better environmental conditions, with less environmental impact, shorter and more comfortable transfer times, using interconnected means of transport, such as trams, buses, trains, metros, cars, bicycles and pedestrians, with multimodal route scenarios.

Smart Mobility integrates ICT technology with traditional mobility infrastructures, such as parking spaces, road and traffic signs, and vehicles, along with new sustainable technologies and infrastructures, such as electric and environmentally friendly vehicles and charging networks, as well as new usage patterns, such as vehicle sharing services like car or bike sharing, for the benefit of better access and quality of mobility for people.

The availability, collection, and dissemination of real-time data is a key element in the design and use of smart mobility services. Appropriate, real-time information, collected by sensors, provided by vehicles, or even by users themselves, and suitably processed, can be used by citizens to save time and improve travel efficiency, especially during commuting, while saving costs and reducing CO2 emissions. This information can then be used by transport network managers to improve services and provide feedback to users.

Smart Environment

Smart Environment refers to the design and practice of environmental resource management for smart cities. Environmental resources are a common property requiring active action by the city government, but also by individuals. In Smart Cities, their management requires synchronous and constant combination of e-democracy, e-governance, and IoT systems.

Smart environmental resource management uses ICT, the IoT, Smart City Governance (e-governance), and the **Internet of People** (**e-Democracy**), i.e., the active involvement of citizens through technology, together with conventional resource management tools to achieve coordinated, effective, and efficient management and development, and conservation of environmental resources.

Smart Environment includes several areas of solutions:

- the **measurement, control, and monitoring of pollution**, through emission and air quality measuring instruments;
- the design or renovation of buildings and services (Smart Building), equipping them with automated processes to control the systems, structure, and use of the building (energy, heating and air conditioning, ventilation, security, video surveillance, waste, ...);
- green buildings;
- urban, green, and open space planning;
- efficiency in the use, reuse, or substitution of resources, including land consumption;
- Smart Utilities, i.e.,
- applications and systems for intelligent and sustainable energy management (Smart Energy Management), including renewable energy, ICT-enabled energy networks, waste management (Smart

Waste Management), drainage and water management systems, monitored to assess the system, reduce pollution and improve water quality (Smart Water Management).

An important and already widespread example is urban street lighting services or Smart Lighting, with light poles often used in a multifaceted way, e.g., for diffuse connectivity or as pollution level detection stations or territorial control stations - for surveillance, traffic monitoring, people/vehicle flows.

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Smart Security

Security in the smart city is a crucial issue. Maintaining security and safeguarding the safety of its citizens are at the top of the ladder of goals. At the forefront of the objectives of a safe city must, therefore, be the reduction of crime and the management of risk situations in emergency conditions (such as an earthquake, a flood, or a pandemic such as the coronavirus).

- **Emergency management:**

On this front, an effective model must be based on the use and integration of different technologies, resources, and processes and, above all, on strong cooperation between authorities, institutions, and actors (such as the police and Civil Protection). The ability to react and the optimisation of efforts in an alarm or emergency situation must be maximised. A network of sensors that give the status of roads, underground utilities, for example, to prevent subsurface runoff and sinkholes can help to build real-time reactions in emergencies.

- **Video surveillance and control rooms for safer cities:**

On the technological front, high-performance video surveillance cameras and CCTV systems, integrated with IoT devices, sensor networks, and dedicated software for data detection and analysis, provide the possibility of detecting unusual events, recognising wanted persons or analysing urban environments in real-time, perhaps in areas considered most at risk.

In a smart city, the use of networked security and video surveillance technologies can improve public safety levels. It is a fast-growing sector, with estimates of an increase in investment in this equipment by local governments of 25-30% over the next 2-3 years[27]. The effectiveness of video surveillance cameras is enhanced by the use of control room solutions and

[27] *Smart city: cos'è, come funziona, caratteristiche ed esempi in Italia • Lumi (lumi4innovation.it)*

Artificial Intelligence algorithms, which enable the cross-checking of numerous cameras and cross-referencing data with proximity sensors.

The International Market

According to analyses by Omdia, some Smart City applications are already proven business cases (e.g. connected CCTV, smart street lighting, etc.). In many regions and countries, governments are making public funds available for smart city initiatives. The initial availability of 5G in cities will also stimulate service providers and suppliers to seek out 5G applications and technology as test beds.

Smart city devices will grow from 117 million in 2018 to 399 million by 2023. The projection for 2025 sees more than 500 million devices worldwide[28]. These include smart light poles (smart lighting), smart parking devices (smart parking), connected surveillance cameras and other public safety devices, smart urban transport, connected waste management and environmental monitoring.

While the prevailing market to date has been North America followed by Europe and Asia, the spread of these devices and associated applications in the coming years will mainly take place in Asia, although North America and Europe will still represent important markets.

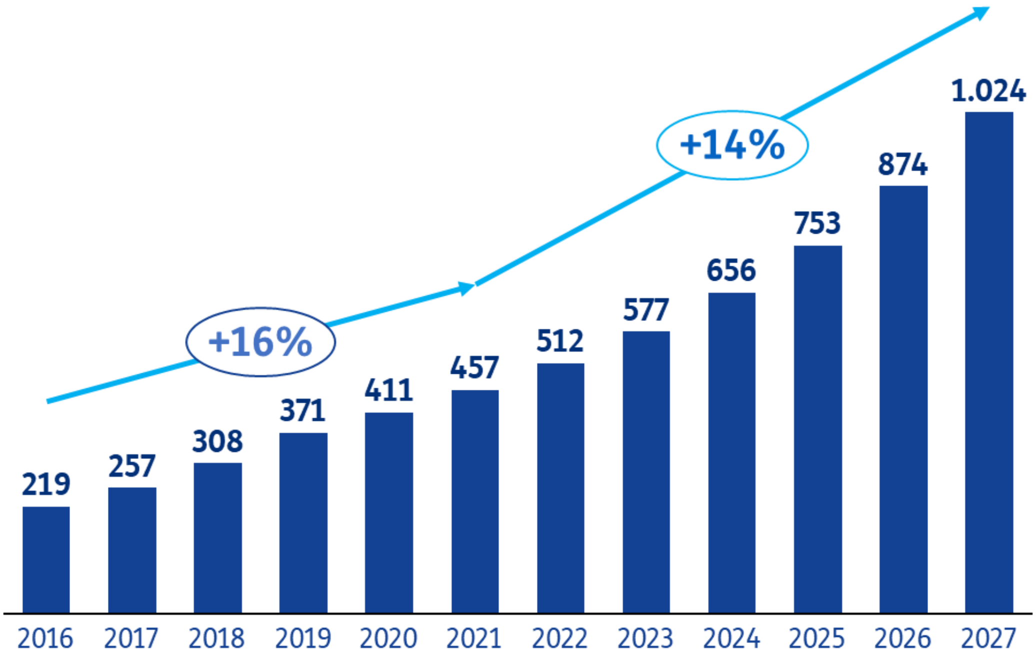
This is due to the fact that Asia has a large number of 'mega-cities' with large and rapidly growing populations. Therefore, urban energy and environmental issues are very present and felt, hence the significant need for Smart Cities. In addition, as there are many areas in Asia with growing cities and high rates of building construction or urban development, this creates a perfect environment to deploy such devices and applications, as deploying such solutions on greenfield sites is generally easier than retrofitting solutions in existing cities and buildings, as is common in Europe and America.

Lastly, the increasing investment in the latest generation of telecommunications networks by Asian telecom operators, first and foremost 5G, will favor the rapid deployment of solutions. According to sector research and analytics firm Markets and Markets, the market has more than doubled between 2016 and 2021, in terms of the value of associated goods and services including services and connectivity revenues, and will continue to grow in the coming years, to over 1 trillion dollars in 2027[29].

[28] *Internet of Things Forecast: Smart Cities and Buildings, 2018-23, OMDIA*
[29] *Smart Cities Market, 2022, MarketsandMarkets*

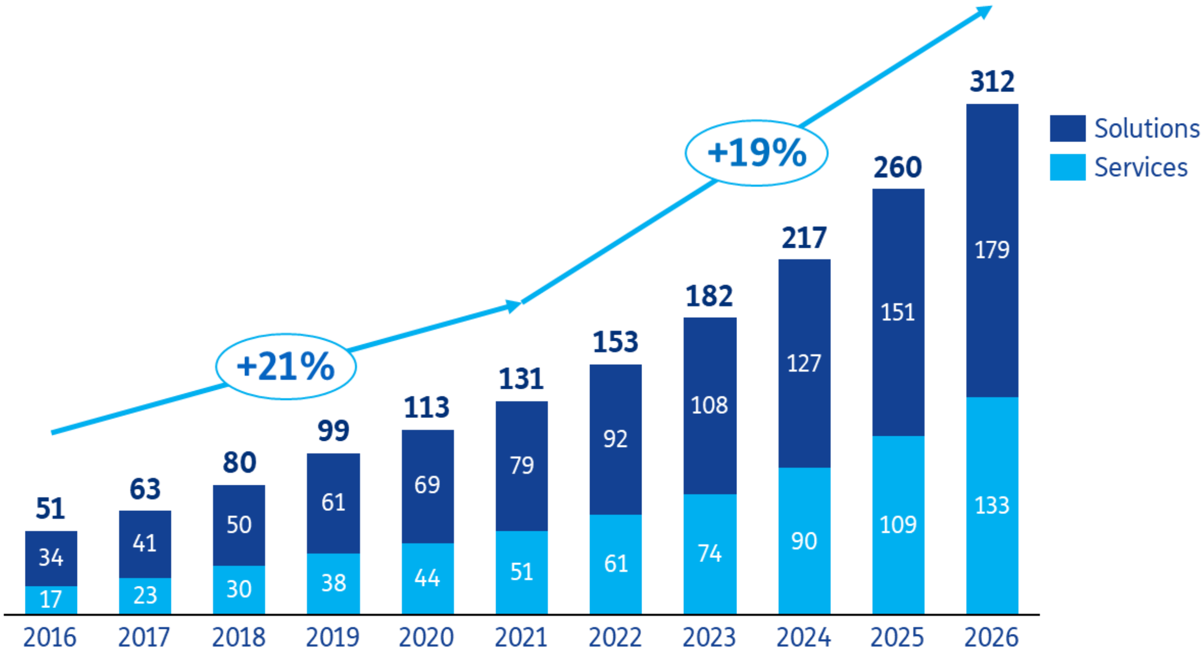
In smart cities, market growth will be driven by increased device penetration and, indirectly, by new associated services, so-called citizen services, such as connected streetlights used to enable additional services, in addition to smart connected lighting management.

Smart City market worldwide ($Mrd)[30]



[30] *Smart Cities Market, 2022, MarketsandMarkets*

IoT/ICT in the Smart City market worldwide, by type of offer ($Mrd)[31]

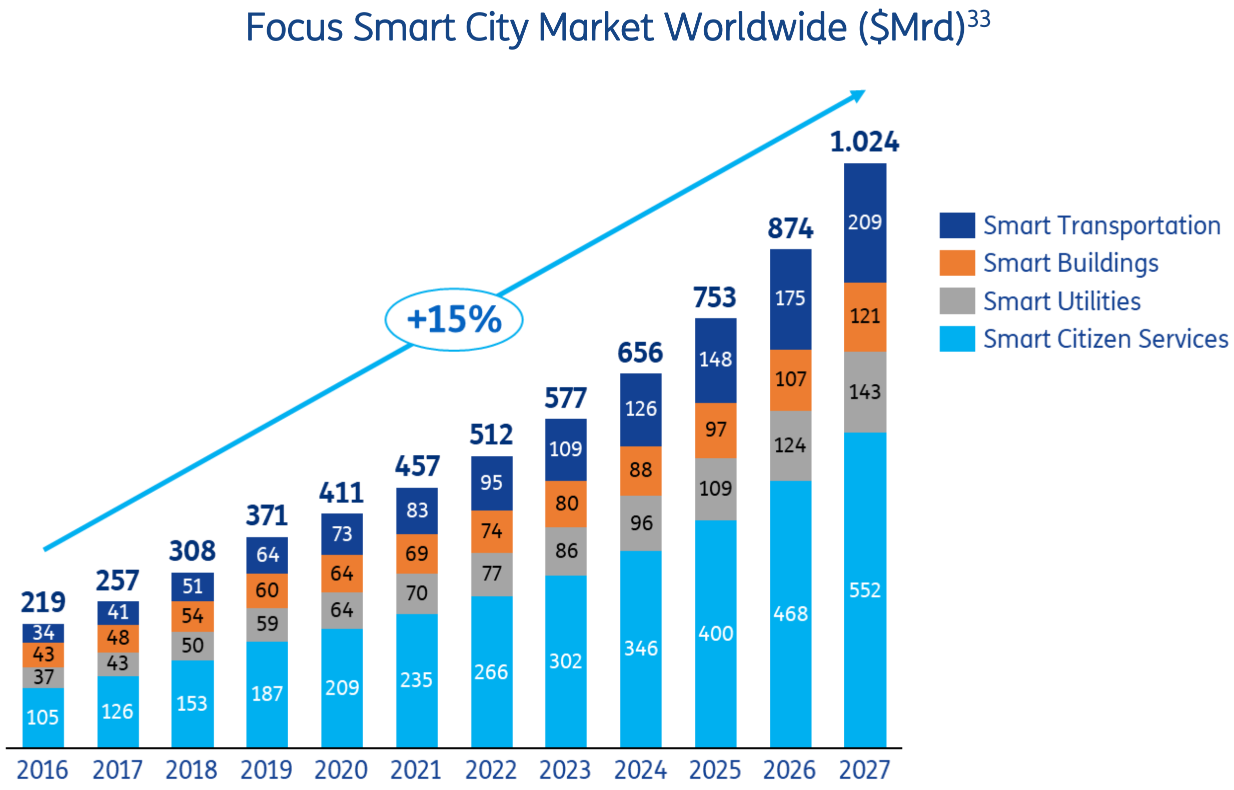


The revenue generated from IoT services in smart cities is only a small part of the total revenue, with most of it coming from the management of platforms, applications, services, devices, and integration and consulting costs. Professional services, such as consulting, deployment, system integration, support, and service, are worth about twice as much as managed services, indicating that the industry component is more dominant than outsourcing. Regarding solutions, the percentage of network management decreases gradually from 18% in 2020 to 14% in 2026, while there is an increase in data management, reporting, and analysis.

According to the International Data Corporation (IDC[32]), the top use cases contributing to spending from 2018 to 2023 are smart grid, fixed visual surveillance, advanced public transport, smart lighting, and smart traffic management, which account for over half of all smart city spending.

MarketsandMarkets predicts that the most significant developments will take place in smart transportation, especially in smart citizen services, such as smart healthcare, smart education, smart public safety, smart street lighting, and e-governance.

[31] *Smart Cities Market, 2022, MarketsandMarkets*
[32] *IDC's Worldwide Semiannual Smart Cities Spending Guide, 2018H2, May 2019*



It is expected that Smart Healthcare will experience the greatest development in terms of both growth and turnover, while eGovernance services will be significant in terms of turnover. Smart Street Lighting is expected to see a high compound increase, but with limited market numbers. This reinforces the idea that the city of the future will increasingly focus on inclusive services dedicated to the health and welfare of citizens, as well as better administrative management of cities, with a view to achieving all-round sustainability.

[33] *Smart Cities Market, 2022, MarketsandMarkets*

CHAPTER 2

Smart Cities in Italy

In Italy, Smart Cities are typically approached in two ways:

- Vertical (much more widespread) addressing one or more specific aspects related to the urban dimension such as mobility, energy, and transport.
- Systemic, which refers to the city as a whole, in its different dimensions, considering it a socio-technical system capable of supporting and enabling innovation.

In 2021, 44.5 million people in Italy (75.5% of the population) lived in urban areas, a number projected to increase to 45.3 million (83.5% of the population[34]) by 2050.

Italy's urban fabric is unique, characterized by:

- Only 14 cities having more than 200,000 inhabitants;
- Another 30 cities having more than 100,000 inhabitants, only one of which is not a provincial capital - Giugliano in Campania;
- Widespread presence of medium-sized cities;
- 85% of municipalities having less than 10,000 inhabitants[35].

The **14 metropolitan cities**, which have replaced the provinces of the same name, are considered "territorial bodies of vast areas.

Law No. 56 of 7 April 2014, also known as the Delrio Law[36], regulates the ten metropolitan cities of ordinary statute regions, including Rome Capital, Turin, Milan, Venice, Genoa, Bologna, Florence, Bari, Naples, and Reggio Calabria.

These are joined by the four metropolitan cities of the special statute regions: Cagliari[37], Catania, Messina, and Palermo[38].

The metropolitan cities in Italy comprise over 36% of the entire population, cover 15.4% of the country's territory, and include 15.9% of its municipalities[39].

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[34] ISTAT data 2022
[35] http://dati.istat.it/index.aspx?queryid=19101 data as at 1 January 2022
[36] Law No. 56 of 7 April 2014, 'Disposizioni sulle città metropolitane, sulle province, sulle unioni e fusioni di comuni" ' published in the Official Gazette No. 81 of the same day
[37] Regional Law No 2 of 4 February 2016, 'Riordino del sistema delle autonomie locali della Sardegna ', published in BURAS No 6 of 11/02/2016
[38] Regional Law no.15 of 4 August 2015, "Disposizioni in materia di liberi Consorzi comunali e Città metropolitane", published in GURS no.32 of 7/8/2015 and ss.mm.ii. (LR n.5/2016, LR n.8/2016)
[39] Istat data 2022

The Italian Metropolitan Cities [40]

Metropolitan City			Population residents as at 01/01/2022	Surface area km²	Density inhabitants/km²	Number of municipalities
	Name	Main municipality				
1.	*Metropolitan City of* CAPITAL ROME	Rome (2,744,945 inhabitants)	4.216.874	5.363	786	121
2.	*Metropolitan City of* MILAN	Milan (1,352,454 inhabitants)	3.214.630	1.575	2.040	133
3.	*Metropolitan City of* NAPLES	Naples (914,406 inhabitants)	2.988.376	1.179	2.535	92
4.	*Metropolitan City of* TURIN	Turin (841,971 inhabitants)	2.208.370	6.827	323	312
5.	*Metropolitan City of* BARI	Bari (315,966 inhabitants)	1.226.784	3.863	318	41
6.	*Metropolitan City of* PALERMO [2]	Palermo (630,170 inhabitants)	1.208.991	5.009	241	82
7.	*Metropolitan City of* CATANIA	Catania (298,994 inhabitants)	1.077.515	3.574	302	58
8.	*Metropolitan City of* BOLOGNA	Bologna (388,087 inhabitants)	1.010.812	3.702	273	55
9.	*Metropolitan City of* FLORENCE	Florence (361,349 inhabitants)	987.260	3.514	281	41
10.	*Metropolitan City of* VENICE	Venice (250,588 inhabitants)	836.916	2.479	338	44
11.	*Metropolitan City of* GENOA	Genoa (559,072 inhabitants)	817.402	1.834	446	67
12.	*Metropolitan City of* MESSINA	Messina (219,104 inhabitants)	603.229	3.266	185	108
13.	*Metropolitan City of* REGGIO CALABRIA	Reggio Calabria (171,246 inhabitants)	522.127	3.210	163	97
14.	*Metropolitan City of* CAGLIARI	Cagliari (148,267 inhabitants)	421.688	1.249	338	17
Total Metropolitan Cities			**21.340.974**	**46.638**	**458**	**1.268**
% on Italy			36,2%	15,4%	-	15,9%
Italy (no. residents)			58.983.122	302.068	195	7.978

Metropolitan cities have been recipients of European Union funds from the National Operational Plan (NOP) Metropolitan Cities 2014-2020, and have also proven to attract significant private investment, such as car-sharing or bike-sharing companies.

[40] *ISTAT data 2022*

The development of Smart City projects in Italy is affected by the country's unique situation, which can be summarized as follows:

- A group of large cities (Genoa, Turin, Bari, Milan, Florence) that have launched structured Smart City pathways through a 'holistic' approach of putting together projects and interventions from a unified perspective, as well as multi-level governance mechanisms between public players, the manufacturing, banking, research, and cultural worlds. This has been made possible by the impetus provided by Italian and European calls for tenders.
- A significant number of municipalities, especially medium-sized ones, which have implemented high-quality interventions in specific sectors (sustainable mobility, e-government, energy efficiency, enhancement of cultural heritage, integrated data management) over the years and are now working towards integration with other areas of city intervention.
- Urban and vast area contexts that still appear to lag behind in adopting planning and intervention models based on the integration of networks, services, and territorial actors[41], mainly due to a significant territorial, dimensional, and infrastructural divide.

The Value of the Market

The focus on the smart city has been steadily increasing in recent years, leading to a proliferation of projects addressing one or more specific aspects of urban life.

A survey conducted by the Politecnico di Milano in 2019 revealed that only 42% of municipalities with more than 15,000 inhabitants had activated at least one smart city project in the previous three years, but this figure had still increased by 6% compared to the previous year. Of those, 31% had initiated one or two projects, and only 11% had activated more projects, while as many as 58% of municipalities above 15,000 inhabitants had not activated any projects during that period[42].

After the Covid-19 pandemic, there has been a shift in the perception of the city. The increase in digitization, the widespread adoption of smart working, the heightened focus on the environment and the circular economy, have all contributed to a growing focus on the Smart City concept.

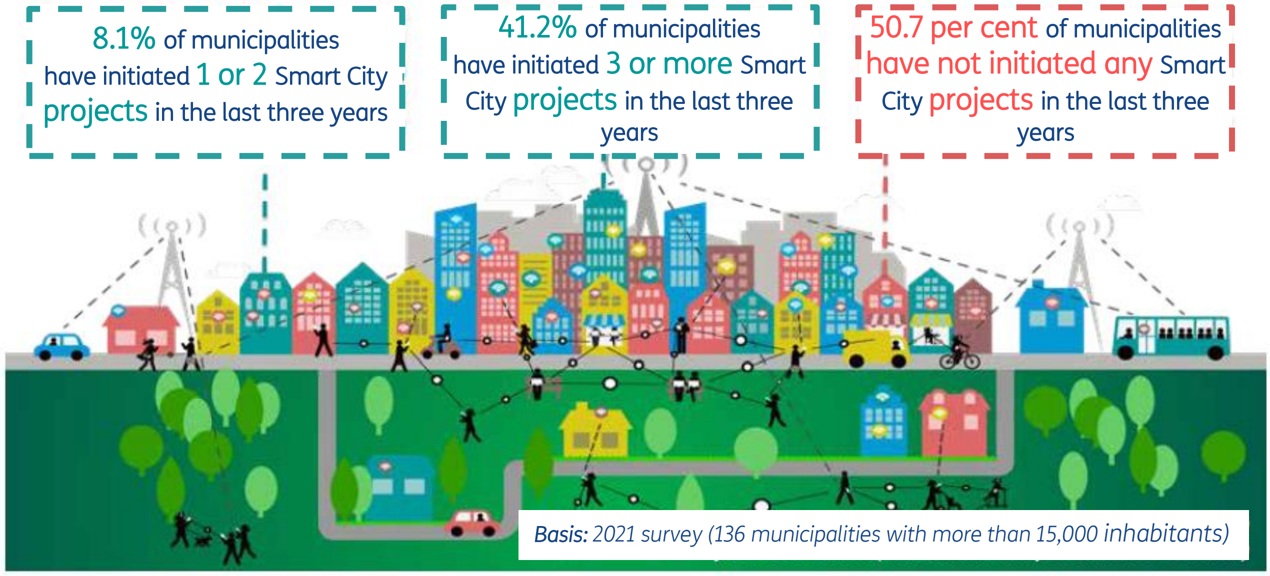
As a result, the number of municipalities that have not undertaken any Smart City projects has decreased to 50.7%, while the percentage of municipalities that have initiated more

[41] *VADEMECUM PER LA CITTÀ INTELLIGENTE, Osservatorio Nazionale Smart City di ANCI in collaborazione con ForumPA , 2013*

[42] *L'Italia delle Smart City. Progetti, Driver di Adozione e barriere da superare, Osservatorio Smart City Politecnico di Milano, Ricerca 2019-2020*

than two has significantly increased. Of those surveyed, 8.1% had initiated one or two projects, and 41.2% had initiated three or more, substantially reversing the percentages of the two groups compared to the previous survey.

Projects launched in Italian municipalities > 15,000 inhabitants [43]



According to a survey conducted by the Internet of Things Observatory of the Politecnico di Milano in the years 2020-2021, the Smart City is considered of great or fundamental importance for 42% of administrators in municipalities with under 15,000 inhabitants, and in 31% of these municipalities, there is a dedicated figure. For cities with over 15,000 inhabitants, the Smart City is a fundamental or very relevant issue for 80% of respondents, and in 72% of municipalities, there is a dedicated figure[44].

The increased attention to the topic by Italian administrators and companies in the sector is well evidenced by the growing trend of the market value. From a value that accounted for no more than 2-3% of the IoT market[45] in the years 2012-2014, the last few years have seen a gradual growth that, despite the presumable setback linked to the Covid-19 pandemic, will reach over 1 billion euros in 2025.

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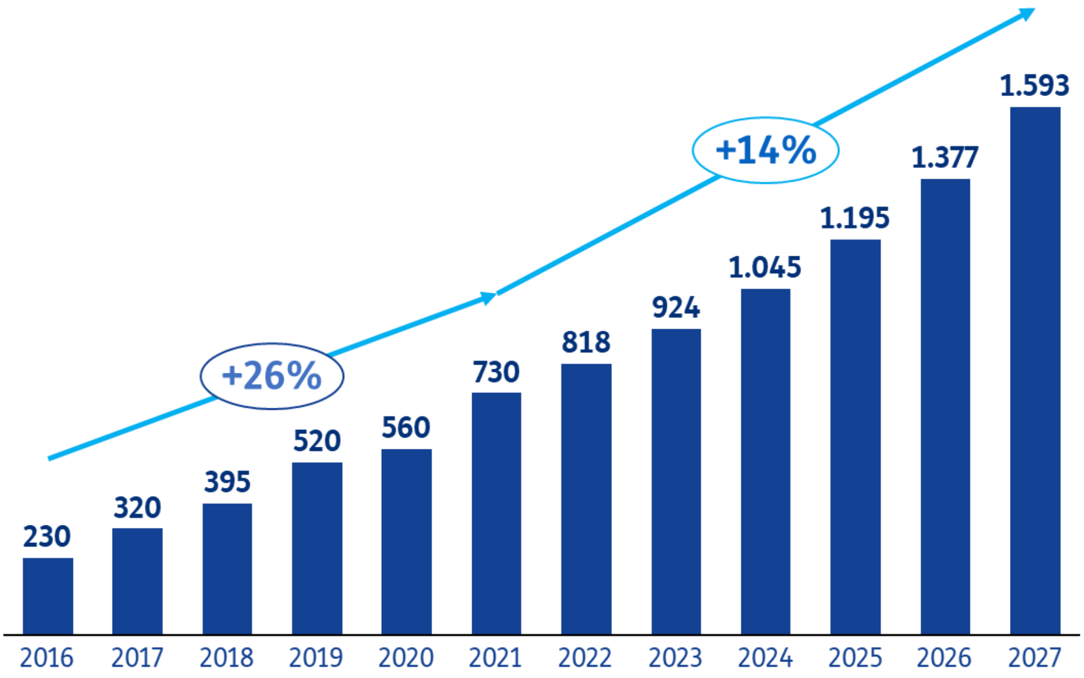
[43] *Smart City: il punto di vista dei comuni italiani, Osservatorio Smart CIty Politecnico di Milano, research 2021-2022, report May 2022.*
The "project" referred to in the graph should be understood as a concept of an application area, meaning that several application areas or "projects" may be included in the implemented project.

[44] *Smart City: il punto di vista dei comuni italiani, Osservatorio Smart City Politecnico di Milano, research 2021-2022, report May 2022.*
Survey base 452 Italian municipalities, of which 316 municipalities <15,000 inhabitants and 136 municipalities >15,000 inhabitants.

[45] *Data from the Internet of Things Observatory Politecnico di Milano, reports from 2013 to 2015*

Smart City Market Italy (€Mio) [46]



In the 2014-2020 EU Horizon 2020 program, funding opportunities for projects directly or indirectly related to Smart Cities amounted to 456.6 billion euros.

The benchmark for participation in European funding is the UN's 17 Sustainable Development Goals 2030.

The 'European innovation partnership on smart cities and communities', an initiative of the EU Commission, has developed a guide for better access to funds allocated for smart cities. The working methodology in the guide was successfully tested in five European cities, including Parma, but Florence, La Spezia, Milan, Pisa, and Genoa also contributed to its realization.

City rankings

Identifying Smart City interventions and Smart Cities in Italy is an operation elaborated from different points of view. The objective is typically to develop a ranking that highlights

[46] *The Centro Studi TIM has elaborated on data from the Internet of Things Observatory at Politecnico di Milano. The data is up to 2021 and is from the Politecnico di Milano report.*

the differences between Italian cities based on the drivers analysed, to see the deviations and actions to be taken, highlighting best practices.

Below we review the main classification works, highlighting the main differences.

EY's **'Human Smart City Index 2022'** represents an evolution from the earlier Smart City Index prepared by EY

The pandemic has triggered a rethinking of cities, which are now perceived as communities putting citizens at the centre again. Citizens use city services for various purposes, such as work, study, entrepreneurship, commuting, healthcare, and tourism. Therefore, the citizen is seen as a city-user. Citizens demand that cities be redesigned to be more responsive to their needs.

EY writes, "If the Human City is the city on a human scale, the Human Smart City is the city that redesigns infrastructure and services by combining citizen-centricity, technological innovation, and sustainability.[47]"

In the model adopted by EY, there must be a correspondence between Smart City readiness (the way a city designs and offers services) and the individual and collective decisions of city-users regarding the use of the city's resources. This correspondence enables the building of sustainable urban development pathways from the city's three main networks: transport, energy, and environment.

The analysis is developed through three strategic axes:

Ecological transition

i.e., how sustainable the infrastructure of cities is, in the different components of transport and mobility, energy, environment (water, green and waste);

Digital transition

These include digital infrastructures (UBB, 5G, sensors), ecosystems of digital services and platforms, the presence of incubators, co-working spaces, fab labs, research centres.

Social inclusion

The administration's ability to listen to citizens (eParticipation), to communicate and involve city-users in the city's activities (digital

[47] *EY Human Smart City Index 2022*

engagement, also via social networks), the social policies implemented (social budget, spending, online services) and the provision of health services.

The study examines 456 indicators grouped into two macro-families: readiness, which measures the ability of administrators to respond to stakeholders' needs, and the behavior of city users in relation to the actions implemented. The analysis covers 109 Italian cities, including provincial capitals, and compares their performance in the three highlighted strands, showing the evolution over the years.

The study correlates readiness and behavior scores, revealing that some cities exhibit unbalanced profiles in either direction and therefore have very different approaches to the "human city." Medium-sized cities in the central-northern region and large cities in the south invest in the Smart City but have not yet garnered virtuous behavior from citizens who are still not very involved, while small cities present a high score in behavior, almost as if the positive behavior of citizens anticipates the results that can be obtained with investments in digitalization and ecological transition. The inclusion of a variable focusing on inclusion and behavioral aspects makes medium and small cities stand out as more "people-friendly" and recover part of the gap compared to larger cities.

The study also assesses the concentration of employees per territory and identifies territories that are drivers for the production chain, with the provinces assessed with respect to "human smartness" and the production chains included in the readiness/behavior matrix.

Finally, the study analyses the relationship between the evaluations obtained by the territories in which the production chains are located and the evaluation of the chains themselves. The results show that five supply chains, such as Technology & Telco, Automotive Manufacturing, Medical Devices, Pharmaceutical, and Media & Entertainment, exceed the national average value and are mostly concentrated in the metropolitan areas of the North and Centre: Milan, Turin, Rome, Bologna, and the wider Emilia area, which have experienced significant digital transformation, ecological transition, and social inclusion, particularly due to the Covid-19 pandemic.

ICity Rank is an annual ranking of Italian cities prepared by Forum Pubblica Amministrazione (FPA), now in its 11th year.

It measures the adaptability of cities on the path to becoming Smart Cities, i.e., cities that are functional, ecological, and livable, and capable of promoting sustainable development by responding to changes through the use of new technologies. The ICR index and ranking from 2017 were constructed from six indices dedicated to the six dimensions of urban quality:

- economic soundness
- sustainable mobility
- environmental protection
- social quality
- governance capacity
- digital transformation

The six indices were compiled from more than 100 indicators, using over 250 variables. The index reference model is continuously evolving, following the evolution of Smart Cities from a phase of pilot projects and innovation to one of introduction, adoption, and consolidation.

For ICR 2022, the digital transformation index is calculated as a numerical index, obtained as the arithmetic mean of the results obtained in eight areas of analysis summarizing more than 150 variables, taken from qualified sources or specific surveys conducted by FPA.

Online services

The first digital transformation examined in ICR is the spread of the possibility for citizens and businesses to access local government services via the Internet.

Municipal apps

Real-time communication and information services for citizens, particularly aimed at mobile devices.

Enabling platforms

These refer to national digital platforms that facilitate access to the tools made available online by administrations, specifically Pago-PA and SPID.

Social PA

The use of social media as a communication tool with citizens and users of the city, including Facebook, YouTube, Twitter, Linkedin, Messenger, Instagram and Telegram.

Open data

This pertains to the published datasets and their interoperability and ease of access.

Opening

This replaces the transparency indicator used in pre-2019 editions and is based on statements of accessibility and reachability of information on local PA websites, as well as on software reuse and cloud usage.

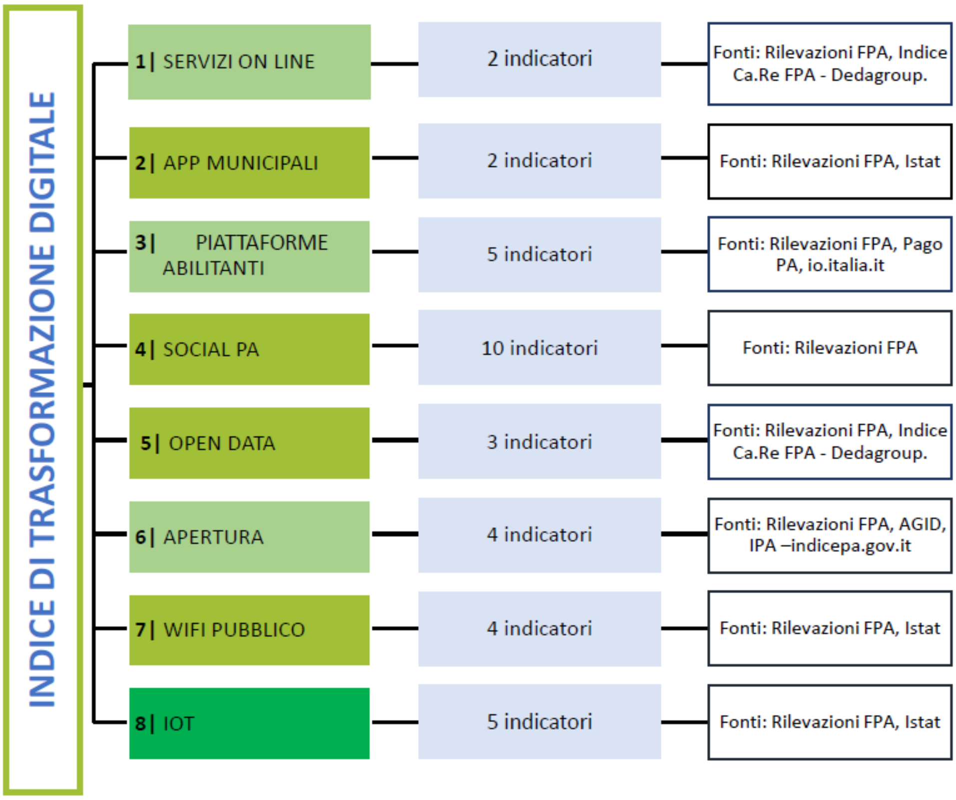
Public Wi-Fi

This takes into account the intensity, i.e. access points per 100,000 inhabitants, density, i.e. Wi-Fi points per square kilometer, communication and information given to citizens and city users on the existence and use of the network, and connection to other supra-municipal networks.

IoT and network technologies

This concerns the digital transformations that are affecting the urban service system, particularly public lighting, the traffic light network and waste collection systems, but also infomobility and green management.

The ICity Rank 2022 reference model[48]



During the 2020s, likely as a consequence of the pandemic and lockdown, the digital transformation process of Italian cities and their administrations accelerated, overcoming organizational and cultural resistance that had hindered development in previous years. Digital innovations often helped manage critical situations by limiting their impact and promoting citizen and association participation.

In 2022, the digital transformation process consolidated, thanks to the greater diffusion and use of enabling platforms such as Sistema Pubblico di Identità Digitale (SPID), a digital authentication system developed by the Italian government to simplify access to online services provided by public administrations and private entities that have joined the system, PagoPA, a centralized electronic payment system developed by the Italian government to facilitate and simplify payments made by citizens and businesses to public administrations, App IO, a public services app developed by the Italian government to facilitate access to public administration services for citizens and businesses, and the financial and operational support of central institutions provided, among other things, with PNRR resources.

Although there has been an overall reduction in the gap between the highest-ranking and lowest-ranking cities, indicating a general diffusion of the Smart City model, the 2022 snapshot again shows Italy divided into three regions, with few exceptions: the first third of

[48] *ICity Rank, Rapporto annuale 2022 – Indice di trasformazione Digitale, Forum PA in cooperation with Enel X and Tiscali.*

the ranking is dominated by cities in the north, the central part by those in the rest of the Central-North, and the final part by cities in the Mezzogiorno.

The size of the cities plays a significant role: no city with fewer than 50,000 inhabitants enter the top band of the ranking.

Legambiente's annual **Ecosistema Urbano 2022** report on the environmental livability of municipalities is now in its 29th edition, produced in cooperation with Ambiente Italia and Il Sole 24 Ore

Legambiente is an Italian environmental association, founded in 1980, that promotes the defense of the environment and the territory in Italy. This report is not primarily aimed at identifying how smart a city is, but by collecting and observing the level of sustainability of an urban environment, it can capture the effects of the gradual digital transformation of cities over time.

There are 18 parameters that determine the environmental performance ranking of municipalities, covering 6 main thematic areas (air, water, waste, mobility, energy and urban environment) and providing for the allocation of a theoretical maximum score of 100 points, constructed on a case-by-case basis according to sustainability objectives.

The scores assigned for each indicator identify the sustainability rate of the real city compared to an ideal city (there is at least one capital city that achieves the maximum points assignable for each of the indices considered).

The average score of the provincial capitals barely rises and stands at 53.41%, a step away from last year's 53.05%.

No city exceeds the score of 80 out of 100, unlike Trento at the height of the pandemic period.

The 2022 report shows that for the 105 cities surveyed on the air and waste fronts (each accounting for 20 percent of the study's final result compared to the 25 percent weight assigned to mobility), parameters that had sometimes improved significantly as a result of the pandemic, rather than settling on a 'new normal,' have instead returned to a normality brought about by the failure to change the main structural situations.

The data analyzed concerns specific environmental performance on:

- pollution
- separate collection
- water network
- public transport

- mobility
- renewable sources

First and foremost, **air pollution**: for fine particulate matter (PM10), as in 2019 and 2020, the limit value for human protection set by an EU directive at an annual average of 40 micrograms per cubic meter is respected everywhere, and the number of towns where the annual average of all the control units is at levels below the target value for health indicated by the World Health Organization (annual average of 20 μg/mc) is increasing. With respect to the annual exceedances of the 50 μg/m3 limit, the situation is also improving compared to 2020. The average value of nitrogen dioxide (NO2) concentrations is falling, with only one city exceeding the legal limit, although the average value for all the capitals is rising. The average value of the control units measuring ozone (O3) concentrations exceeds the threshold for the protection of human health in 45% of the municipalities that provided the data.

In line with the trend of recent years, the average percentage of separate **waste** collection in the capitals improved to 61.5%, more than two percentage points higher than in 2020 and three points higher than in 2019. The legal target of 65% set for 2012 has been reached by 52 cities. Ten capitals exceed the 80% threshold.

On the other hand, **waste generation** is on the rise again - the average value reaches 526 kg per capita, almost at pre-pandemic levels (it was 514 kg per capita in 2020 and 530 in 2019).

Public transport, after the general slump highlighted last year with the post-pandemic data, registers here and there timid improvements but confirms for the capitals general performance that is far from full recovery and in any case is not reorganized in such a way as to counter the marginalization of the peripheral territories, which has a more significant impact on the most fragile populations, those living in peri-urban areas; growth in the number of cars registered in urban areas is slowing down to just below last year's average figure, but the car fleet remains among the highest in Europe.

Small positive signs come from the growth in **cycling** data (km of tracks and infrastructure) and from the spread of **solar energy** (thermal or photovoltaic) installed on public buildings, whose average value reaches 5.41 kW/1,000 inhabitants. As far as **water losses** are concerned, cities where more than 30% of water is dispersed remain roughly constant (rising from 53 in 2020 to 52 in 2021), while the average value of water that is dispersed remains at 36.0%.

Legambiente highlights the political-administrative gaps that need to be bridged to achieve a citizen-friendly urban ecosystem, and in doing so it goes beyond the ranking of the capital cities to broaden its gaze and propose a new concept of urban civilization more in line with the 17 United Nations Sustainable Development Goals (UN SDG).

For this reason, in addition to drawing up a ranking of the most virtuous cities, the report highlights successful dedicated initiatives as best practices to be imitated by other urban centers. The aim is to make a contribution to the global reflection on the future of cities, starting from positive experiences, from those who have succeeded over the years in implementing significant actions and changes in a green key.

This year, a total of 17 best practices have been awarded by Ecosistema Urbano, all of them mainly related to sustainable mobility, urban green areas, and redevelopment of urban areas and paths of inclusion.[49]

The Digital Strategy Report 2019 by the Energy & Strategy Group of Politecnico di Milano focuses on **'Smart City and Digital Energy in Italy: an overview of lights and shadows'.**

The report examines a sample of 15 cities, considered the "smartest" in Italy, and takes stock of the projects implemented in the field of energy efficiency. In particular, it maps the evolution and time positioning of the projects undertaken to identify the different levels of maturity and penetration of the solutions in the city.

There are three pillars on which the report's analysis rests:

#1 **Living**, both public and private, thus declining in:

- Smart Building
- Smart Lighting

#2 **Mobility**, concerns mobility solutions and infrastructures:

- Smart Mobility
- Mobility sharing
- Public transport
- Infrastructure

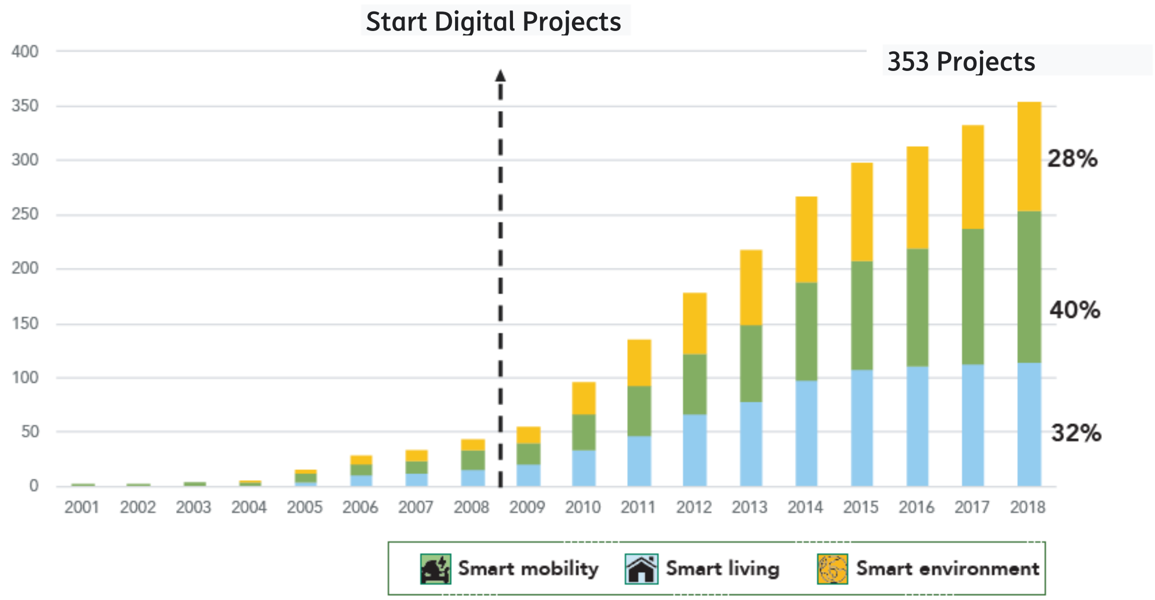
#3 **Environment**, covering energy production, grid infrastructure, waste management:

- Renewables
- District heating
- Smart grid & Storage
- Waste management

[49] *Ecosistema Urbano 2020, 2021 2022, Legambiente in cooperation with Ambiente Italia and Il Sole 24 ore*

Within these three areas, key transformation projects were identified, both at the city and Italian level. In Italy, 353 active projects have been identified, mainly in the energy sector, which can be classified according to their characteristics in the three different areas [50].

Distribution of Smart City projects across the 3 pillars[51]



Although this report refers to 2019, it still highlights some interesting features, as it is able to demonstrate a different process of technology adoption by cities, depending on their size. Large cities followed different strategies but adopted the same action strategy, focusing on one area at the beginning and then adding innovation projects in the others. Smaller cities, on the other hand, immediately took a less focused approach, developing projects in several areas simultaneously. This multifocal approach is the most effective for the transition of cities towards the Smart City.

[50] *Digital Strategy Report 2019 by the Energy & Strategy Group of the Politecnico di Milano*
[51] *Digital Strategy Report 2019 by the Energy & Strategy Group of the Politecnico di Milano*

Start-ups changing the face of smart cities and buildings

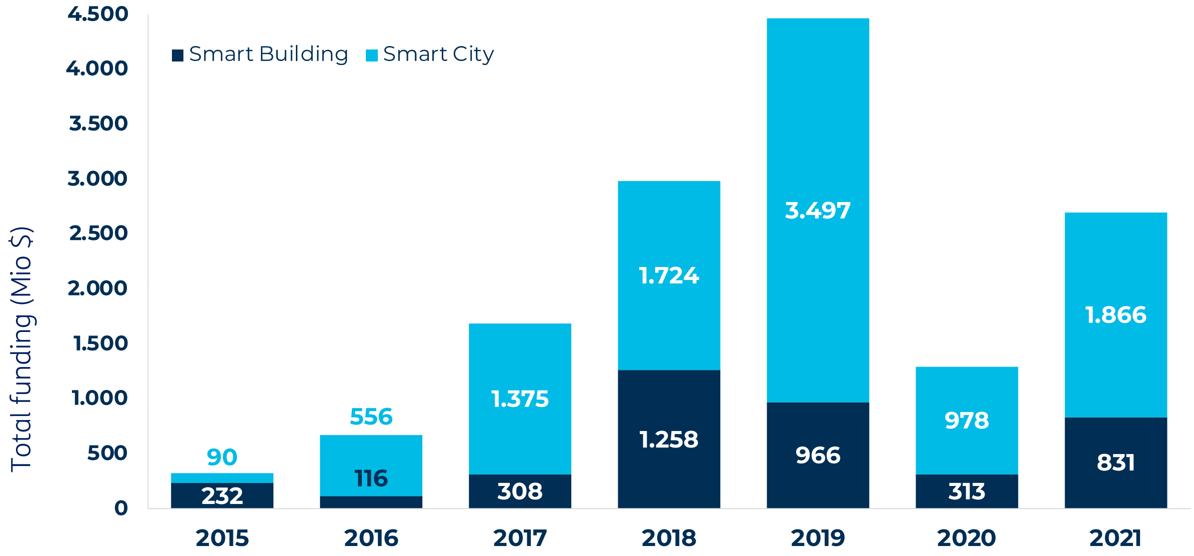
The findings of the study by the Internet of Things Observatory and the Startup Intelligence Observatory of the Politecnico di Milano show that:

The context generated by the Covid-19 pandemic and beyond has accentuated the relevance of environmental sustainability and digitalization, issues that find a natural application within buildings and cities. Both in the Italian context and on the international scene, people are increasingly interested in the adoption of digital technologies capable of making buildings more efficient, reducing polluting emissions, improving citizens' mobility, and making cities safer places. In fact, the Smart City and Smart Building innovation frontier is evolving rapidly, with more and more innovative start-ups finding important business opportunities in these markets.

The research analyzed 307 IoT start-ups worldwide that have developed solutions in the Smart City or Smart Building field. Of these, 212 received funding from institutional investors (69%) in the last three years, raising a total of 8.5 billion dollars, with an average of around 39.9 million dollars per start-up. From a financial point of view, it is the United States that is leading the way, with a total of 3,749 million dollars raised (44% of total funding) and an average of 49 million dollars received by each start-up. Italy, on the other hand, still lags behind, showing difficulties in raising funding (37 million dollars raised, 0.4% of total funding, and 3 million dollars on average per start-up).

Looking at the number of companies operating in each field, there is a prevalence of Smart City start-ups (58% vs. 42% Smart Building), which raised a total of 10 billion dollars (vs. 4 billion raised by Smart Building start-ups). This difference is partly due to the distribution of the number of startups and partly to the higher average funding obtained by startups that have developed smart city initiatives (82.7 million dollars for Smart City startups vs. 38.3 million for Smart Building startups).

Edited by the Digital Innovation Observatories of the Politecnico di Milano

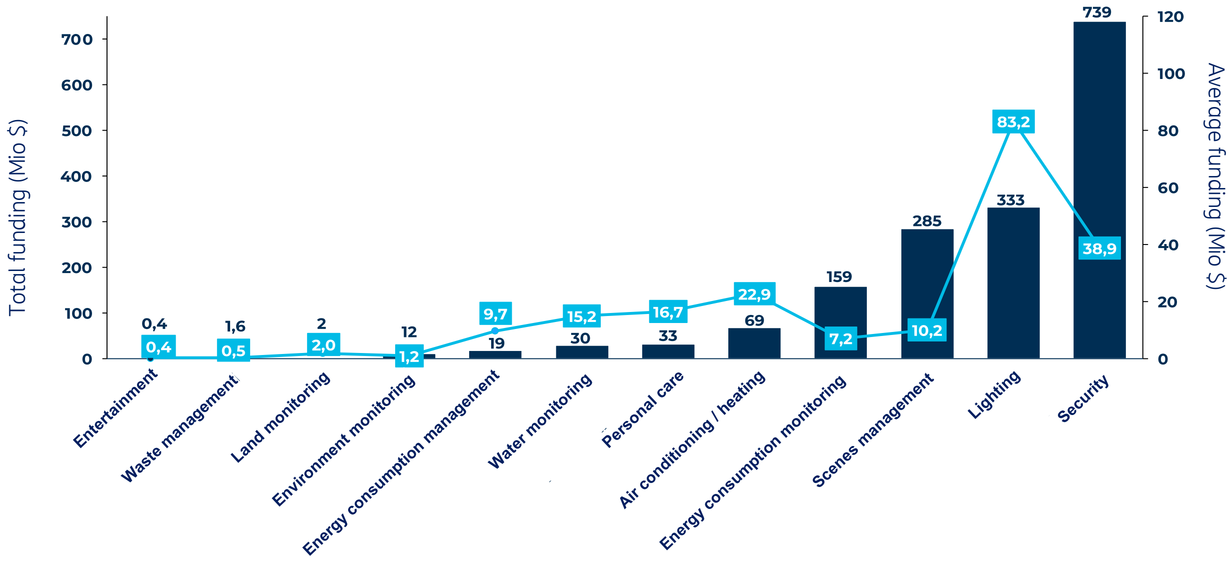


Basis: 227 funded start-ups

In terms of offerings, the software component is the one on which start-ups focus the most, either taken individually (16% of the total), combined with a service (17%), or proposed on the market together with hardware devices (24% and in first place). The percentage relating to the latter type of offer grows even more if we consider only the Smart Building application area: 40% of the start-ups dealing with intelligent buildings, in fact, propose the hardware + software package. Also statistically significant is the proportion of start-ups whose offer includes all three items at the same time (hardware + software + service, 14% of the total).

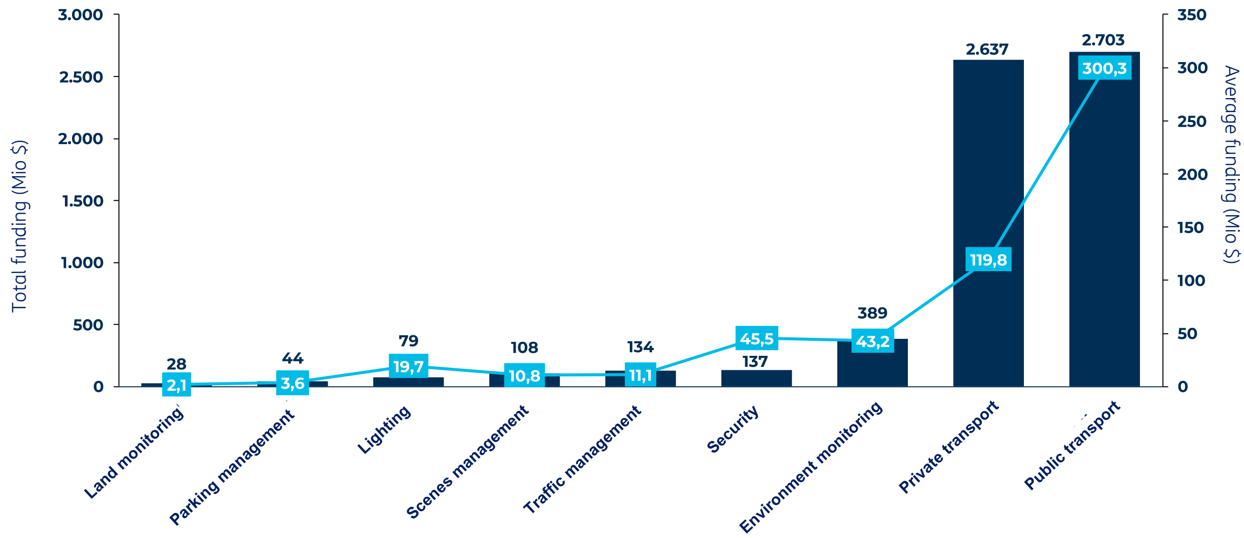
The products/services offered by the start-ups were further classified based on their main functionalities. For Smart Building start-ups, Scenario Management is the most popular functionality, accounting for 25% of the total. This is followed by Energy Consumption Monitoring (23%) and Security (16%). While occupying the third place, Security is the functionality with the highest value of total funding, with 739 million dollars raised in the last three years. Looking at average funding, however, it is startups working in Lighting that receive the most funding, with 83.2 million dollars per start-up, which is far higher than the 38.9 million dollars for startups working in Security, which is second when looking at average funding.

Edited by the Digital Innovation Observatories of the Politecnico di Milano



Basis: 102 Smart Building start-ups financed in the years 2019-2021

In the Smart City sector, the topic of mobility is one of the most popular, with Private Transport, Traffic Management, Parking Management, and Public Transport applications accounting for a total of 52% of the sample. There is also a clear correlation between the degree of deployment and funding received by start-ups operating in the mobility field. Public and private transport are, in fact, the functionalities with the highest value of total funding, having raised 2.7 and 2.6 billion dollars respectively in the last three years. The same trend can be observed for average funding, with the two types of transport dominating the ranking of the most funded functionalities.



Edited by the Digital Innovation Observatories of the Politecnico di Milano

The importance of 5G in the digital transformation of cities

5G represents one of the most significant drivers for transforming cities into smart environments. The objective of this analysis is to estimate the impact of IoT in general and 5G in particular on the smart city environment.

Cities already have a significant number of people and businesses that are relatively digitally connected through various fixed and wireless communication technologies. However, the transformative capacity of 5G is unparalleled compared to previous technologies. It not only enables faster communications (enhanced Mobile BroadBand), but in the Smart City environment, it also enables services that require the exchange of large amounts of data (Machine-Type Communications) and those that require ultra-low latency (ultra-Reliable & Low Latency Communications), meaning a reaction time in the order of 1-5 milliseconds.

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Indeed, cities contain large numbers of people and businesses that are already relatively digitally connected through various fixed and wireless communication technologies. However, the transformative capacity of 5G is unparalleled compared to previous technologies, as it not only enables faster communications (enhanced Mobile BroadBand), but in the Smart City environment it also enables services that require the exchange of large amounts of data (Machine-Type Communications) and those that require ultra-low latency (ultra-Reliable & Low Latency Communications), meaning a reaction time in the order of 1-5 milliseconds.

The main benefit of 5G is therefore not in improving communication and the availability of information, but in enabling new classes of services. In this paper, however, we will only examine those that have an impact in terms of environmental sustainability improved using 5G technologies, declined along the following lines:

- public and private urban mobility;
- the environment, understood as air quality, the impact of waste cycle management and light pollution.

The close dependence between these two directions is evident. At the European level, urban transport is responsible for about a quarter of the transport sector's CO2 emissions and 69% of road accidents occur in cities[52]. Phasing out conventionally fueled vehicles from

[52] *LIBRO BIANCO - Tabella di marcia verso uno spazio unico europeo dei trasporti - Per una politica dei trasporti competitiva e sostenibile COM (2011)*

the urban environment[53] is one of the factors that can contribute most to reducing oil dependency, greenhouse gas emissions and air and noise pollution. This will have to be complemented by the development of adequate recharging/refueling infrastructure for new vehicles. Better transport through enhanced wireless communications can offer great advantages in reducing congestion, and this should subsequently lead to reductions in hydrocarbon consumption and lower emissions and CO2 in cities.

In cities, the shift to less polluting modes of transport is facilitated by the smaller variety of vehicles required and the high population density. There is a wider availability of public transport alternatives as well as the possibility of walking and cycling. Cities suffer more from the problems of congestion, poor air quality and exposure to noise pollution. The main benefits of reduced traffic congestion can be reduced noise and pollution problems. A reduction in pollution and particulate matter can be particularly beneficial for those who live in cities and have respiratory diseases. Furthermore, proper management of the waste cycle allows for a healthier and more livable urban environment. A reduction in lighting, or rather its targeted use, contributes greatly to the sustainability of urban centers.

Already from these initial considerations, it becomes clear that the complexity of the Smart City lies not only in the multiplicity of objectives for the various stakeholders, in the alternative technological choices that can be evaluated and implemented, but also and above all in the need for interoperability, in the multiplicity of functions and services that the installed sensors (alone or in collaboration with each other) can provide and the information, direct and second level, that interacting with each other can generate. All these variables and opportunities must be evaluated by the citizen decision-maker in relation to the costs to be incurred, the objectives to be achieved and the time required. We therefore speak of Urban Intelligence, which aims to help the city decision maker assess the impacts that different solutions and strategies have on the Smart City, and which we will see in more detail in a dedicated monograph, edited by the CNR, at the end of this work.

[53] *The term 'powered by conventional fuels' refers to vehicles using non-hybrid internal combustion engines.*

CHAPTER 3

A still fragmented landscape

Smart City projects

The first positive point to note is the decrease in project testing and the shift to executive projects, as highlighted by the annual analysis of the Smart City observatories at Politecnico di Milano. In fact, at the end of 2019, executive projects accounted for 39% of total new projects, with a 19% growth over the three-year period from 2016 to 2018[54].

In the Italian context, public institutions, such as municipalities, have often played the role of promoter and coordinator/committer for diffuse projects. However, in projects involving small towns, this role is often taken up by a coordination involving several municipalities, often with the support of project partners.

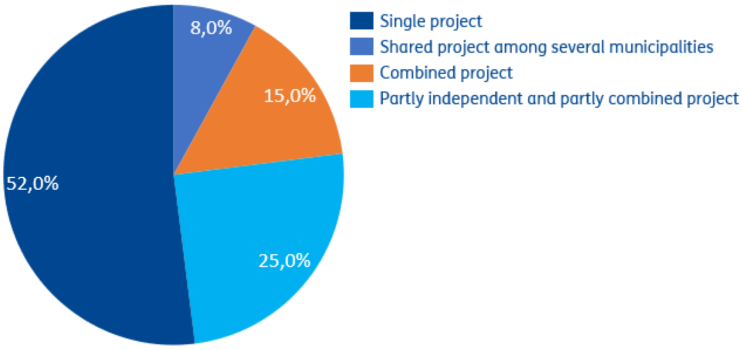
Moreover, as previously mentioned, these projects are often still SILOS projects, which means they are not part of an extended urban transformation program, but rather focus on a specific area.

These observations are also reflected in the research by the Milan Polytechnic Observatory. According to a survey published at the beginning of 2020[55], more than half of the projects in the three-year period from 2016 to 2018 were stand-alone, and slightly over half of the others were joint 360° programs implemented by a single municipality. Only 10% were the result of coordination between several municipalities. The research published last year showed little change in this situation, also indicating a direct relationship between the implementation of stand-alone projects and the small size of the municipality.

[54] *L'Italia delle Smart City. Progetti, Driver di Adozione e barriere da superare, Osservatorio Internet of Things Politecnico di Milano, Ricerca 2019-2020*

[55] *L'Italia delle Smart City. Progetti, Driver di Adozione e barriere da superare, Osservatorio Internet of Things Politecnico di Milano, Ricerca 2019-2020*

Types of projects launched in Italian municipalities [56]

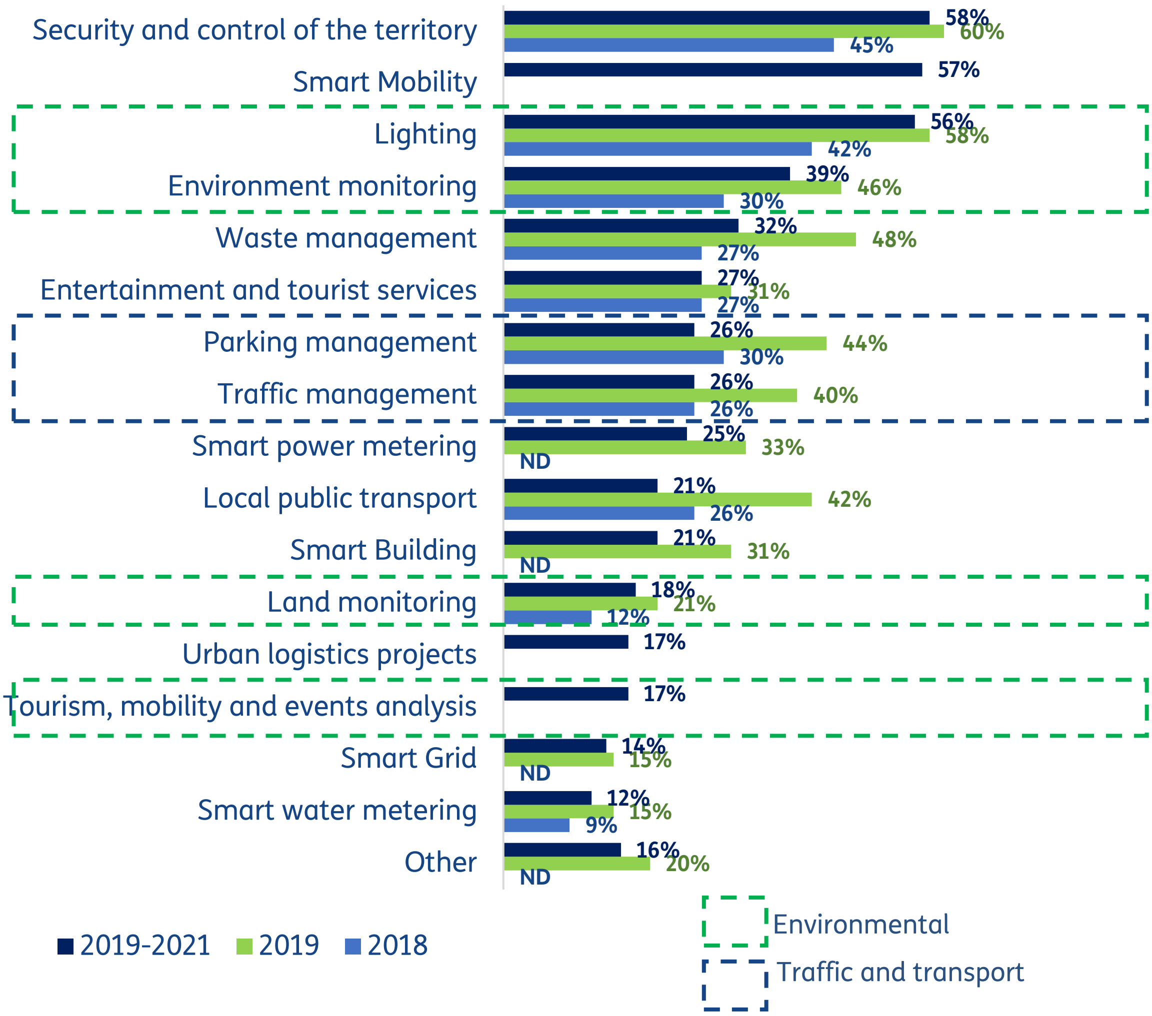


There are therefore still few integrated Smart City programs, while the innovativeness of the projects adopted is increasing. According to the Politecnico di Milano, let's see what types of projects cities have invested most in. The two priorities for cities are safety and lighting, which were already highlighted in the previous year's report as the two areas of greatest interest.

Compared to the growth in 2019 over 2018, we highlight the areas related to sustainability, which had the largest YoY increases: Waste management +21%, Environmental monitoring +16%, Land monitoring +9%.

[56] *Smart City: il punto di vista dei comuni italiani, research 2021-2022, Osservatorio Internet of Things Politecnico di Milano, report May 2022.*

The areas of the projects [57]



The topics of sustainable mobility and traffic, on the one hand, and environmental sustainability, on the other, are second only to safety, although in reality, safety is sometimes used precisely to discourage deviant behavior, especially in the environmental sphere (e.g., occasional roadside dumping). It should be noted that new categories of projects have appeared in the new report, namely those of Smart Mobility, which probably also partially replace local public transport projects, projects in the field of tourism in connection with events and mobility, and the new urban logistics projects.

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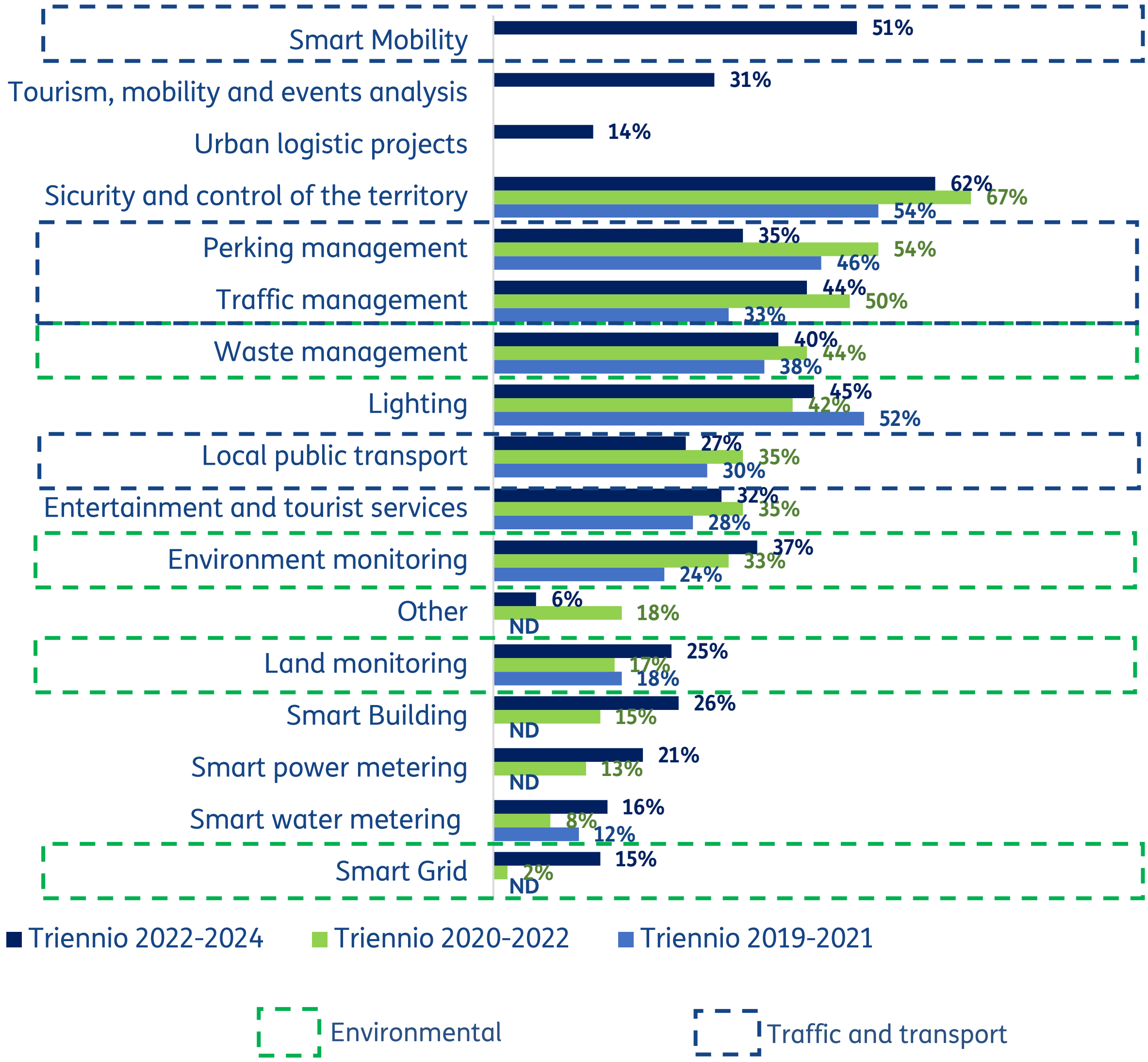
[57] *Survey Politecnico di Milano 2019, base: 94 projects initiated by 48 Italian municipalities > 15 thousand inhabitants; Survey Politecnico di Milano 2018, base: 107 Italian municipalities > 15 thousand inhabitants, and Smart City: the point of view of Italian municipalities, research 2021-2022, Osservatorio Smart City Politecnico di Milano, report May 2022. Note that: Smart Power Metering in the 2019-21 Report is listed as Smart metering, Smart Water metering in the 2019 report was referred as "Water resource management". By similarity of meaning the definitions have been put together.*

Investment priorities for the next three years[58]



In terms of the priorities expressed by municipalities for upcoming projects, safety remains the top concern, but both traffic management and environmental issues are gaining in importance. Projects related to urban traffic management, tourism analysis, mobility and events, and waste collection are on the rise. The boundaries between mobility optimization and efficiency, control and energy saving, and environmental protection and sustainability are becoming increasingly blurred, with solutions often impacting multiple themes.

[58] *Survey Politecnico di Milano 2019, base: 94 projects initiated by 48 Italian municipalities > 15 thousand inhabitants; Survey Politecnico di Milano 2018, base: 107 Italian municipalities > 15 thousand inhabitants; and Survey Politecnico di Milano 2021-2022, base 107 Italian municipalities.*

The Observatory found that the major driver for intervention choices is to provide better services to citizens and to introduce new services, with some variability based on the size of the municipality. While improving services is the primary driver for both municipalities above and below 15,000 inhabitants (63% and 73% respectively), introducing new services is more important for larger municipalities, with 46% of responses compared to 35% for smaller ones. There is a growing awareness of the new service opportunities offered by IoT technologies, supported by the increasing interest in environmental sustainability, which has risen from 30% in 2018 to 38% in 2019[59], peaking at 43% in the largest municipalities and standing at 31% in the smaller ones.

The largest cities also highlight the benefits that Smart City projects can provide in improving city governance, with 22% citing improved decision-making capacity. However, there is still a lack of sufficient skills (67%), understanding of the value of data (38%), and adequate IT tools (38%)[60]. The research also shows that municipalities struggle to turn to more innovative financing methods than traditional ones. In particular, 42% and 38% of smaller and larger municipalities, respectively, stated that they wanted to use internal resources without presenting a business plan[61]. Furthermore, most municipalities do not know how to assess the impacts in terms of sustainability and cost savings of their interventions, either at the forecasting stage or at the final balance[62], as revealed by interviews carried out during the 2019 survey.

This issue becomes critical at a time when NRRP funding is available for both the Ecological Transition and the Digitization of public administration (PA), as well as for the realization of sustainable infrastructures. The ability of municipalities to present executive projects and deliver them as required by legislation is essential.

[59] *L'Italia delle Smart City. Progetti, Driver di Adozione e barriere da superare, Osservatorio Internet of Things Politecnico di Milano, Research 2019-2020; Smart City: a che punto siamo in Italia, Osservatorio Internet of Things Politecnico di Milano, Research 2018-2019; Smart City: il punto di vista dei comuni italiani, Research 2021-2022, Osservatorio Smart CIty Politecnico di Milano, report May 2022.*

[60] *Smart City: il punto di vista dei comuni italiani, research 2021-2022, Osservatorio Smart CIty Politecnico di Milano, report May 2022.*

[61] *Smart City: il punto di vista dei comuni italiani, research 2021-2022, Osservatorio Smart CIty Politecnico di Milano, report May 2022.*

[62] *L'Italia delle Smart City. Progetti, Driver di Adozione e barriere da superare, Osservatorio Internet of Things Politecnico di Milano, Research 2019-2020.*

Smart mobility in Italian cities

Evidence from the study by the Connected Car & Mobility Observatory of the Politecnico di Milano

The topic of Smart Mobility continues to be central to Italian municipalities: almost 9 out of 10 municipalities (88%) with a population of over 15,000 consider it relevant or fundamental.[63] The pandemic has helped to strengthen the level of attention with which municipalities regard smart mobility: for 42% of respondents, it has made the issue even more of a priority, while only 5% consider it less urgent than in the past.

The growing relevance of the topic is accompanied by an increase in the spread of Smart Mobility initiatives: the number of municipalities that have launched projects will rise from 41% in 2019, to 50% in 2020, to 59% in 2021. While it is important to test new solutions, technologies, and business models in a frontier area such as Smart Mobility, it is also necessary to have the courage to transform the multitude of pilot projects into fully-fledged solutions that bring value to municipalities and citizens.

As of now, in fact, 1 in 2 projects is still in the embryonic phase of experimentation. Smart Mobility also owes its growing attention to the huge investments that have been made at the national level in recent years. One example, above all, is the National Recovery and Resilience Plan (PNRR), through which more than 60 billion euros have already been allocated between 2021 and 2026 for smart mobility and enabling infrastructure.[64] Reducing the scope to only sustainable and smart mobility, the investments still reach a significant share of 14.3 billion euros (see Figure 4: Smart Mobility & PNRR).

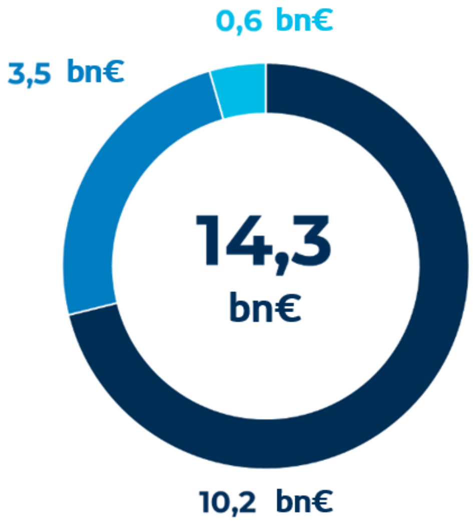
These include, for example, the renewal of green train and bus fleets (3.7 billion euros), the implementation of dynamic monitoring systems for the remote control of bridges, viaducts, and tunnels (1 billion euros), the adoption of hydrogen mobility solutions (0.9 billion euros), the development of electric charging infrastructures (0.7 billion euros), the strengthening of cycling mobility (0.6 billion euros) and Mobility as a Service (MaaS, 40 million euros).

Edited by the Digital Innovation Observatories of the Politecnico di Milano

[63] *Source: survey sent to over 700 Italian municipalities with more than 15,000 inhabitants (15% response rate), Sett. 2021, Osservatorio Connected Car & Mobility del Politecnico di Milano*

[64] *Enabling infrastructures refer, for example, to 5G, high speed, train/port/airport modernization.*

In accordance with previous years' findings, the lack of economic resources and skills remains the primary obstacles to initiating Smart Mobility projects. Italian municipalities are increasingly feeling the skills gap, which ranks highest on the list and receives approval from as many as 69% of the surveyed municipalities (+8%). In contrast, the lack of economic resources drops to second place (58%, -10%) compared to the previous survey, possibly due to the funds allocated by the PNRR. Next are the challenges related to bureaucracy: 34% of municipalities identify the 'administrative machine' as one of the main barriers (+25%).



Sustainable mobility

Missions	bn€
Electric buses	0,3
Hydrogen	0,9
Renewables and batteries	1
Bus fleet renewal and green trains	3,7
Development electric charging infrastructure	0,7
Development mass rapid transport	3,6

Smart City / Infrastructure management

Missions	bn€
Integrated urban plans	2,5
Safe roads	1

Micro mobility and MaaS

Missions	bn€
Mobility as a Service	0,04
Improvement of cycling mobility	0,6

PNRR opportunities for Smart Mobility / Source Osservatori Digital Innovation - Politecnico di Milano (www.osservatori.net)

In fourth place among the barriers is the difficulty of coordination between municipalities and other actors involved (29%, +6%). Analyzing current collaborations, there are already multiple actors with whom municipalities come into contact, confirming that Smart Mobility projects are not only the responsibility of the Public Administration: municipalized companies are confirmed as the first actor involved (61%), followed by other municipalities, in a broader context of "smart land" (44%), providers of sharing services (28%), law enforcement agencies (26%) and universities and research centers (23%). Looking at the data on future collaborations, the support of innovative start-ups (56%), delivery companies (30%) and road operators (25%) is very relevant for the development of new projects in the coming years.

One of the central issues when it comes to barriers to project start-up remains that of data. What emerges today, however, is a scenario with lights and shadows: on the one hand, it is positive that more than half of the municipalities involved in the survey have started to use the data collected (59% in 2021 vs. 44% in 2020); on the other hand, there is still a lot of work to be done for their profitable use. In fact, as many as 3 out of 5 municipalities that use collected data do so for internal purposes (61%), while only in 27% of cases are data shared with other public or private companies, and in 12% are used to offer services to citizens.

Edited by the Digital Innovation Observatories of the Politecnico di Milano

Realised projects - Use case

Urban mobility

We have seen that improving urban mobility is a key aspect of enhancing citizens' quality of life.

Smart Mobility refers to a set of solutions for intelligent use of transport systems, optimizing routes, reducing transfer times, making journeys safer, and minimizing environmental impact.

Among the most prevalent use cases of Smart City initiatives, those related to mobility are undoubtedly a priority.

In Italy, Control Rooms have been established to monitor the city, movement of people, and traffic and mobility in general, both public and private.

Venice - the Smart Control Room

In September 2020, the city of Venice[65] introduced the Smart Control Room and the new local police headquarters.

The Smart Control Room collects data and video streams from various control centres, sensors located throughout the territory, and different structures that have expert operators within the structure, including ACTV/AVM, Centro Maree, the Municipality, Local Police, Civil Protection, Venis, and Veritas.

The data provided by sensors is also harmonised with information from telephone cells and around 400 video surveillance cameras in the Venice area.

All this data is visually displayed on the Control Room's video walls, enabling operators to verify any intervention requirements in real-time. They can determine the number of people in the city, types of boats in the canals, passage of public transport (road and water), control of the flow of tourists, weather forecast, and parking situation.

[65] *https://live.comune.venezia.it/it/2020/09/invio-corretto-isola-nuova-del-tronchetto-oggi-la-presentazione-della-nuova-sede-della*

The Smart Control Room in Venice functions as a type of 'control tower', where a considerable amount of data flows in real-time. This includes information such as the number of people in the city, the types of boats in the canals of the historic city, the passages and potential delays of public road and water transport, the control of the flow of tourists, the weather forecast, and the parking situation. All this data is then processed using Big Data and Artificial Intelligence technology, with due respect for privacy, to activate predictive tools that aid the governance of the city and its territory. These tools enable public services to be optimized and new ones to be planned based on scientific data.

Florence - The Smart City Control Room project

The city of Florence has approved the final project financed with European funds for the improvement and streamlining of urban mobility through the Smart City Control Room, a super operational management center of the Florence Smart City, of which smart mobility represents the first aspect. The Smart City Control Room will be a physical space equipped with all the city's mobility control systems, with large video walls, workstations with video terminals for operators, and a large table from which the coordinator will also manage the traffic 'brain'. This will be achieved using already operational tools such as the network of sensors to measure the flow of vehicles circulating on city streets, the remote control system for traffic lights, the interfacing of the tramway control system with that of the city's traffic light systems, real-time communication of traffic criticalities due to accidents or urgent interventions, the system for monitoring the occupancy status of the parking structure, and the availability of the real-time position of buses.

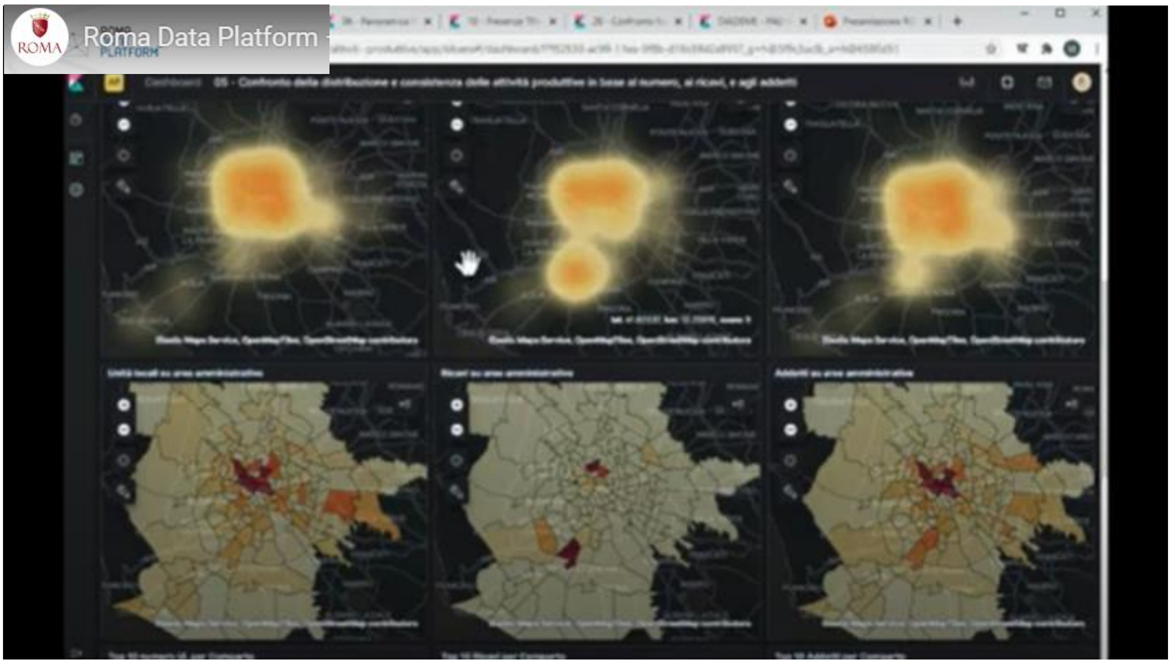
The Smart City Control Room in Florence will enable the real-time monitoring of the mobility situation, allowing for prompt interventions if necessary. The data collected will also be available on "IF," the official infomobility app of the municipality of Florence, thus empowering citizens to become active participants in the mobility system.

In this Control Room, all the interfaces of the management systems affecting the road network will be available to all operators in the room, including the traffic supervisor, IF infomobility platform, public lighting control, road maintenance information system, Cityworks and Geoworks for ordinances, connections to other operational centers operating in the municipality, and the camera network for traffic monitoring. The main stations of the operators of various public service and mobility managers in Florence, such as Silfi, the Global Service manager, SAS, the Municipal Police, Publiacqua, Toscana Energia, GEST, ATAF, the multi-channel service of 055055, ALIA, etc., will also be housed in the Control Room, along with the Municipal Police[66].

Rome - Roma Data Platform Project

Roma Data Platform[67] is the new platform that provides a control 'dashboard' to visualize in an integrated and simultaneous way the data concerning the fundamental aspects of the daily life of a large city: we are talking about the number of people in the city and the analysis of the flow of tourists, the weather forecast, the real-time parking situation, public transport schedules and the flow through the of ZTL (Limited Traffic Zones) gates, but also the state of economic activities, with advanced levels of detail and much more.

[66] *https://www.comune.fi.it/comunicati-stampa/firenze-smart-city-la-centrale-di-gestione-e-monitoraggio-trova-casa-accanto - January 202*
https://www.comune.fi.it/system/files/2020-09/Scheda_2_2_1f.pdf
https://www.snap4city.org/download/video/barc19/fi/video-REPLICATE-CdF.mp41
[67] *https://www.gruppotim.it/it/innovazione/news-innovazione/Roma-data-platform.html*



The Data Platform enables the simultaneous collection and analysis of a multitude of data, even on a geo-localized basis, by exploiting the integration of public and private data. Its ultimate aim is to support institutions and companies in their strategic investment and development choices and to improve their decision-making processes.[68]

Mobility, tourism, and security

Novara Smart City

The Municipality of Novara, a city in the Piedmont region of northwest Italy, has chosen to implement multi-channel and multi-platform applications covering several sectors: tourism, culture, and security.

In the citizens and tourists' dedicated area, a mobile application (App) provides information on tourist-cultural initiatives, ticketing for access to the city's museums and cultural services, and for the promotion and use of rooms and spaces available at municipal facilities. The solution also allows citizens to interact with the municipality using a special reporting form in an innovative, simple, and effective way, integrating with existing platforms.

To enhance, promote, and improve security in the area, a dedicated video surveillance application was developed that manages and interacts with the video camera system located in the municipality. Through big data analysis of population movement flows,

[68] *https://www.gruppotim.it/it/innovazione/news-innovazione/Roma-data-platform.html*

surveys in the fields of tourism, culture, and territorial security, it will be possible to monitor the movements of inhabitants and visitors to optimize transport, urban mobility, and security. This also enables predicting the volume of people during events and the routes followed by tourists, or to identify areas that require a special tourist offer[69]. All these measures will be in full compliance with current privacy regulations.

Destination Assisi

This is the name of the tourist presence detection system developed by the City of Assisi, in the province of Perugia in the Umbria region of central Italy, and its technological partners. The objective is to draw a qualitative and quantitative profile of tourists, studying their origin, profiling them based on sociological characteristics, and identifying the most visited routes and places. This helps to better manage flows, orient activities and services offered, and promote the territory effectively and efficiently. The system is based on big data analysis of population movement flows obtained through mobile data.[70]

Smart Parking

Smart parking is one of the most effective initiatives to improve time management for citizens, reduce urban traffic, and decrease emissions. It is an information system that provides citizens with the availability and location of available parking in a given area. At the core of smart parking is IoT technology: parking sensors, installed at parking spots, communicate with a central platform using a wireless infrastructure. An app, distributed to citizens, reports the nearest available parking space to the user, as well as the time needed to reach it. Typically, these apps also allow users to pay for parking fees via their smartphones, which are limited to the actual parking time.

Mantua - Smart Parking

An ongoing example has been launched by the city of ongoing example was launched by the city of Mantua[71] in the Lombardy region of northern Italy.

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[69] TIM Press Note 15 February 2019
[70] https://www.assisinews.it/economia/destinazione-assisi-in-citta-linnovativo-progetto-per-rilevare-le-presenze-con-i-cellulari/
[71] Politecnico di Milano 2020 - L'Italia Delle Smart City - Progetti, Driver di Adozione e Barriere da Superare

The Municipality of Mantua, in collaboration with the University of Modena and Reggio Emilia and a group of public and private partners, has launched the Smart Parking project. The aim is to monitor and inform motorists of the availability of parking spaces in real-time in the city centre. This will help to streamline traffic flow, reduce parking search times, and ensure greater accuracy and transparency in the payment of parking fees.

The system will initially be tested in the centre of Mantua, in Corso Vittorio Emanuele, using 66 sensors connected to a dedicated network to evaluate the service's effectiveness. Among the features planned are real-time monitoring of parking space occupancy, availability, and average duration of parking.

The App will also inform users of electric car charging stations, and any abuse, such as illegal parking in charging areas, can be remotely detected. Similar projects have been developed in other cities, including Bergamo and Cagliari.

Smart waste bins - the projects in Cremona and Mantua

One of the main challenges in waste disposal in public areas is associated with the management of waste bins distributed throughout the city. The use of Smart Bins can solve the problem of filling them and result in the saving of fuel used for collection vehicles. Smart Bins use a series of sensors to detect the level and type of waste in real-time. The collected data, including frequency and time of use, is then sent to a central information system, which optimizes the waste collection process by reducing the use of resources and vehicles. This improves the service by allowing for prompt action on full bins and the environment by reducing collection transfers and minimizing the time waste remains in the bin.

Other benefits resulting from the amount of data collected include a greater geo-referenced understanding of waste consumption and production in the area, the ability to monitor collection activity, and the opportunity for continuous service improvement.

The solution relies on particularly energy-efficient technologies that enable the smart box to operate for years without the need for connection to the power grid. This is thanks to low-power IoT sensors and communication systems, long-lasting batteries, and optimized control software.

Similar initiatives are being carried out by the Municipality of Mantua (Citybin) and the Municipalities of Milan, Brescia, Bergamo, and Cremona (Smart Bin Project, which involves around 13,000 smart bins).

CHAPTER 4
Sustainability in Smart Cities

Traffic: urban congestion

Urban traffic congestion is one of the main problems in cities. It heavily impacts the quality of life and health of citizens, carrying with it numerous consequences that have been studied.

Time lost in traffic is one of the main consequences. According to **Inrix's Global Card Scorecard 2022**, the ranking that analyses **mobility** and **urban congestion** in more than 1,000 cities in 50 countries around the world, **Palermo** ranks tenth globally and third in Europe, with 121 hours lost in traffic per driver. Many other Italian cities are unfortunately at the top of the ranking, including **Rome**, 13th globally (and 5th in Europe) with 107 hours lost in traffic, **Turin**, 29th (86 hours lost), and **Milan**, in 61st position with 59 hours[72].

With most countries around the world having loosened COVID-19 restrictions, 2022 should have been a year of reappearance closer to the behavioral norms of 2019 - social gatherings, concerts, parties, work, and study venues reopened without constraints. Yet, that trend was interrupted when oil prices started to rise worldwide and were further exacerbated by Russia's invasion of Ukraine.

According to Inrix, from January to June 2022, the price of regular motor petrol increased by 49% and the price of diesel increased by just over 55%, according to the US Bureau of Transportation Statistics. While prices fell slightly in the second half of the year, they ended 2022 at 58% higher than pre-COVID-19 levels. Rising fuel prices and inflation have had a significant negative economic impact on real wages, commuting, air travel costs, goods movement, supply chains, and have led to higher costs of goods and services worldwide. INRIX found that the typical US driver commuting to work spent over 1,325 dollars on fuel in 2022, compared to 1,010 in 2021.

According to the TOM TOM Traffic Index 2021, the first Italian city in the world rankings is Palermo in 36th place with 82h lost and 36% congestion, followed by Rome (54th with 75h lost and 33% congestion), Messina (61st with 73h lost and 32% congestion), Catania and Naples (80th and 85th respectively with 30% and 29% congestion). In the ranking, however, Palermo is in the company of Paris (37th place with 82 hours lost and 36% congestion), and

[72] *Inrix, Global Traffic Scorecard 2022*

Rome of London (55th place, 75 hours and 33% congestion) [73]. Among other things, a 2012 report by the Grattan Institute correlates time lost in urban traffic with a decrease in social contacts. It seems that 10 minutes spent on the road equals 10 per cent fewer human relationships established.[74]

One indicator of traffic congestion is the number of private cars on the road: in 2021, there were about 15 million vehicles (33.5% of the national total)[75] circulating in metropolitan cities in an area of 15.4% of the national total[76]. Of these, more than 13.5 million were private cars (34% of the national total) [77].

Congested traffic also leads to an increase in accidents, unnecessary use of energy resources to get around, worsening air quality, and environmental quality.

Traffic congestion not only results in a higher number of accidents but also contributes to the inefficient use of energy resources for transportation, leading to a decline in both air and environmental quality.

The effects of traffic congestion on noise pollution in urban environments are significant. Projections indicate that by 2030, traffic-related noise pollution will increase by 7.8% in urban areas and 16.4% in suburban areas, posing a considerable health risk to approximately 120 million people (compared to 109 million in 2017). In certain Italian cities, over 50% of the population is exposed to noise levels exceeding tolerable health limits, underscoring the need to address this growing concern.

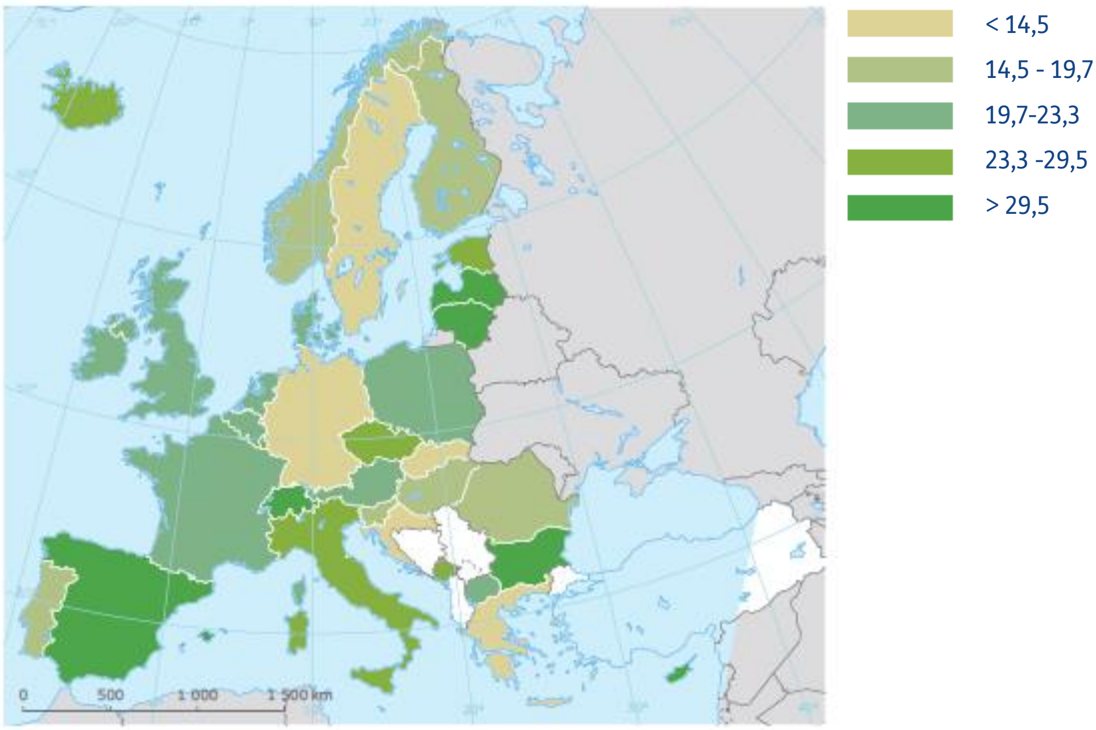
In order to mitigate the effects of noise pollution, the EU recommends several strategies, such as increasing quiet and pedestrian areas and transforming urban layouts to move high-traffic routes away from residential zones. Despite Directive 2002/49 EC on environmental noise, which stipulates noise mapping and action plans to reduce noise pollution, not all European countries have fully implemented these measures. Italy[78], for instance, has been subject to infringement proceedings since 2013 due to non-compliance with the directive.

Researchers conducted a study of 25 European capitals, published in Environment International, a peer-reviewed open-access scientific journal focusing on environmental science and health, to assess the impact of noise pollution on public health. The parameters set for the European Union, based on a World Health Organisation (WHO) recommendation of 53 dB Lden, were considered. Two primary health outcomes were examined: high noise annoyance and ischemic heart disease (IHD) for adults exposed to

[73] *TOM TOM Traffic Index 2021*
[74] *Social Cities, Grattan Institute 2012*
[75] *ACI data 2022*
[76] *ISTAT data 2023*
[77] *ACI data 2022*
[78] *https://www.assoacustici.it/4815/procedure-di-infrazione-europee-sul-rumore-ancora-aperte/*

noise levels above 55 dB Lden. The median proportion of people affected by traffic noise annoyance is 8.8%, while in Rome, it rises to 11.5%. Noise pollution related IHD fatalities in the European capitals studied were estimated at 3,608 globally, which could be avoided by adhering to the parameters recommended by the WHO[79].

Population EU countries exposed to high average levels of road noise pollution (val %) [80]



Over the years, various solutions have been devised to discourage the use of private vehicles, primarily by enhancing public transport networks, gradually replacing public transport vehicles with less polluting models, such as electric buses, and promoting intermodal transport. UITP, the International Association of Public Transport, estimates that by 2030, 52% of buses operating in the world's cities will be electric[81].

COVID-19 has significantly altered when and how people choose to travel. Some cities and towns have experienced substantial increases in cycling, while others have witnessed decreases. In most urban areas, public transport usage remains below 2019 levels,

[79] *Impact of road traffic noise on annoyance and preventable mortality in European cities: A health impact assessment, AA.VV., published in Environment International, Volume 162, April 2022, 107160.*
[80] *Unequal exposure and unequal impacts: social vulnerability to air pollution, noise and extreme temperatures in Europe, 2019, European Environment Agency*
[81] *Urban Ecosystem 2020, Legambiente*

although the number of bus passengers has risen faster than the number of train passengers[82]. Bearing this in mind, several cities have introduced 30 km/h speed limits in traffic zones, which not only moderate traffic and increase safety for pedestrians and cyclists but also help reduce private car use while encouraging active mobility and public transport.[83]

It is therefore crucial to address traffic and mobility, making it smarter and more intuitive. Innovations in this area are effective when systematized and linked by a common platform that collects data and coordinates, or aids in coordinating, various aspects.

A key benefit, which has had multiple impacts and will have even more with the introduction of 5G, is the improved road traffic management facilitated by better wireless communication, enabling enhanced coordination of transport networks:

- Increased access to real-time information for travelers should enable faster travel times within and between cities.
- Increased access to real-time information for transport service providers should enable better coordination between different modes of transport in multimodal transport sections.
- More information on traffic flows and trips should enable traffic controllers to better manage traffic in real time and reduce congestion.
- Improved traffic information, conversely, ought to help drivers bypass congested routes, allowing them to complete their journeys more efficiently.

Enhanced wireless communications, coupled with reduced costs and/or improved reliability of connectivity, offer opportunities for growth in the development of information platforms. These new platforms should be highly scalable hybrid architectures, combining database elements and search technologies to facilitate dynamic and adaptable access to information.

The benefits of IoT and 5G

One of the unique features offered by 5G is its ability to support data exchange in large-scale M2M/IoT networks. This will facilitate improved traffic management using road sensors and real-time data from vehicles.

[82] *Inrix, Global Traffic Scorecard 2022*
[83] *European Transport Safety Council, 2019*

Congestion in the EU-28 Member States is primarily found in and around urban areas, costing approximately 100 billion euros, or 1 per cent of the European Union GDP, each year. This expense comprises fuel, vehicle operating costs, and a monetary revaluation of time costs. The Centre for Economics and Business Research (Cebr) predicts that these costs will increase by 50 per cent between 2013 and 2030[84]. This equates to a compound annual growth rate of 2.41 per cent, resulting in congestion costs of 133 billion euros in 2025 and 150 billion euros in 2030 for the European Union.

Applying this figure to Italy, with a 2022 GDP of 1,889 billion euros[85], suggests that if congestion in urban areas amounted to 1% of GDP in 2022, over 18 billion euros would be lost in that year. Assuming the same compound annual growth rate of 2.41% as for the European Union, it is estimated that the cost of congestion in 2027 will be around 24 billion euros or approximately 1% of Italy's projected GDP in 2027[86].

A.T. Kearney forecasts that one of the benefits of dynamic IoT data access will be a 10% reduction in congestion[87]. If we conservatively assume that 60 per cent of traffic congestion occurs in urban areas[88] and the mentioned 10 per cent reduction in congestion is due equally to 4G LTE, 5G and the enhanced deployment and use of sensors, we can conclude that smart cities could provide an economic benefit of roughly 1.1 billion euros for Italy in 2023 and 1.4 billion euros in 2027. This would yield a cumulative value of approximately 1.1 billion euros between 2023 and 2027.

Traffic: the economic and social impact of accidents

Closely associated with traffic is the accident rate, which refers to the number of accidents occurring annually within a city.

One of the most notable advantages of utilizing 5G functionalities, acknowledged but infrequently quantified in smart city research, lies in enhanced traffic management. The data exchange and analytical capabilities of 5G offer opportunities to alleviate traffic congestion, pinpoint problematic traffic zones, and minimize accidents.

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[84] http://www.cebr.com/reports/the-future-economic-and-environmental-costs-of-gridlock
[85] International Monetary Fund, World Economic Outlook Database, October 2022.
[86] 2,186.16 billion, according to International Monetary Fund, World Economic Outlook Database, October 2022
[87] The internet of things: a new path to European prosperity, January 04, 2016 https://www.middle-east.kearney.com/digital/article/-/insights/the-internet-of-things-a-new-path-to-european-prosperity
[88] 5G Impact Europe_EC

The previous section analyzed the benefits of traffic reduction. This section focuses on the quantitative benefits of lowering accident rates. While 5G will be crucial, it is important to recognize that sensors within vehicles will also contribute to accident reduction. Many of these 'in-car' sensors can operate independently, without needing integration with a 5G network or platform.

In the EU27, the overall number of road fatalities stood at 45 per million inhabitants in 2021, as opposed to 66 per million in 2011, establishing it as the world's safest region in terms of road safety[89]. Nonetheless, the Commission maintains that the exceptional decrease in fatalities during 2020 and 2021 was primarily a result of Covid-19 and the associated measures. There is no certainty that this progress will be sustained once normality resumes. Between 2012 and 2021 in the European Union, 57,095 road deaths were averted, compared to the number that would have transpired had the rate remained consistent with that of 2011.

Moreover, the Commission estimates that for every life lost, six more individuals suffer severe injuries with life-altering consequences (approximately 120,000 people in 2021). The external and social cost of road accidents has been calculated at around 280 billion euros, accounting for roughly 2 per cent of the European Union GDP [90].

Attributing a monetary value to the prevention of loss of life may raise ethical concerns, but it enables the costs and benefits of road safety measures to be evaluated objectively, allowing for the most effective allocation of generally limited resources.

The European Union has set an ambitious long-term objective of achieving near-zero fatalities by 2050[91] ('Vision Zero'), with a corresponding goal for serious injuries. In March 2017, the Valletta Declaration[92] was adopted in the Council conclusions, establishing a target for the first time to reduce serious injuries. EU transport ministers aim to halve the number of serious injuries in the European Union by 2030 compared to 2020 figures. The Valletta Declaration proposed new interim targets, including a 50% reduction in the number of road fatalities between 2020 and 2030 and a 50% reduction in the number of serious injuries during the same period.

The report by the European Transport Safety Council (ETSC) underscores the lack of uniformity in definition or counting methods across different European countries, making it impossible to compare the number of serious injuries between them. Based on the

[89] *Ranking EU progress on road safety - 16th Road Safety Performance Index Report, European Transport Safety Council (ETSC), June 2022*

[90] *Road safety: Europe's roads are getting safer but progress remains too slow, EU Commission- mobility and transport press release - 11 June 2020*

[91] *European Commission (2011), White Paper 'Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system', COM (2011) 144 final.*

[92] *Council of the European Union (2017), Council Conclusions on Road Safety endorsing the Valletta Declaration (Valletta, 28-29 March 2017), 9994/17, http://data.consilium.europa.eu/doc/document/ST-9994-2017-INIT/it/pdf.*

limited data available, there has been a slower reduction of serious injuries as compared to deaths, with only an 18.5% decrease over the last decade.

While Member States are making progress towards convergence in road safety, the 2021 data reveal substantial differences in mortality rates among European countries, with a fourfold disparity between the highest and lowest risk groups.

Norway continues to lead with the lowest road deaths at 15 per million inhabitants, followed by Malta with 17 deaths per million inhabitants in 2021. Sweden, Switzerland, Denmark, and the United Kingdom have lower road deaths at 27 per million. Romania and Bulgaria have the highest number of road deaths with 92 and 81 deaths per million inhabitants, respectively. Some countries have made significant progress, with Norway and Lithuania halving mortality rates from 2011 to 2021. Many other countries have had reductions of around 30%, while Romania and the Netherlands have only experienced a 12% drop, making them the worst performers in terms of road safety.

The European Transport Safety Council (ETSC) determined that the financial value of a fatal accident in 2011 was 1.84 million euros. In 2004, the 15 EU countries experienced 1.16 million road accidents, with an average accident value of 112,000 euros. Using this figure for road accidents, it is projected that the cost of road accidents in the EU will be 82.8 billion euros by 2025, with an estimated 739,000 road accidents. By 2030, the cost is expected to decline to 71.8 billion euros[93].

The situation in Italy

In Italy, the trend in road accidents and mobility has been influenced by the pandemic situation and measures to control it. In 2021, there were 151,875 road accidents with personal injuries, marking a 28.4% increase from 2020. There were 2,875 victims, representing a 20.0% increase, and 204,728 injured, a 28.6% increase. Although these figures are higher than those recorded in 2020, they remain lower than those of 2019, with victims down by 9.4%, injuries down by 15.2%, and accidents down by 11.8%. In 2019, there was already a reduction in road deaths (-4.8%), accidents (-0.2%), and injuries (-0.6%). However, the road fatality rate is expected to increase from 40.3 to 48.6 deaths per million inhabitants between 2020 and 2021, and from 52.6 in 2019, causing Italy to slip from 12th to 13th place in the European ranking. Road deaths have fallen by 30.1%[94] compared to 2010.

[93] *16th Road Safety Performance Index Report, European Transport Safety Council (ETSC), June 2022*
[94] *Road Accidents - Year 2021, ACI-ISTAT*

In terms of fatalities, the categories with the smallest decreases were motorcyclists (-18.0% since 2001, -26.8% since 2010, -0.4% since 2019), cyclists (-37.4% since 2001, -13.6% since 2010, -9.5% since 2019) and pedestrians (-54.4% since 2001, -24.2% since 2010, -11.8% since 2019).

Cyclists and motorists have made the greatest gains in terms of fatality reduction over the past 20 years due to a variety of factors, including increased awareness of proper helmet and safety device use, and significant advances in vehicle safety device technology. The impact of the increasingly widespread circulation of electric, zero-emission micro-mobility vehicles, such as electric scooters, remains to be seen in the coming years, given the fragility of their drivers.

These vehicles were officially granted the status of 'vehicle' with Budget Law No. 160 of 27 December 2019, and were assimilated to bicycles in terms of traffic regulations. The Infrastructure Decree (Decree Law 121/2021) also introduced changes in the Highway Code to regulate their circulation.

The social cost of road accidents in 2021, calculated according to the methodology[95] and parameters[96] set by the Ministry of Infrastructure and Transport, is estimated to be 18.2 billion euros at prices discounted to 2022[97]. This represents 1% of the national GDP, down from 21.4 billion euros in 2010 (-21% in 10 years). The social costs of road accidents represent an estimate of the economic damage suffered by society because of such events. The economic loss is not a direct expense incurred by society, but rather the economic quantification of the burdens imposed on it due to the consequences caused by a traffic accident.

The benefits of IoT and 5G

Approximately 50% of deaths resulting from road accidents occur on the spot in the minutes immediately following the event or during the journey before reaching the hospital. Of those who make it to the hospital, 15% of deaths occur within 4 hours after the accident, and 35% after 4 hours[98]. Effective post-accident care, such as prompt and proper medical attention provided at the scene and during transport to medical facilities, can mitigate the consequences of injuries. Several studies indicate that reducing the time

95 Social Costs of Road Accidents - Year 2019, Ministry of Infrastructure and Transport - Department for Transport, Navigation and Information and Statistical Systems - Directorate General for Road Safety

96 Ministry of Infrastructure and Transport, Directorate General for Road Safety, 2012. "Study to assess the Social Costs of Road Accidents".

97 Elaboration Centro Studi TIM on data The value of money in Italy from 1861 to 2021, ISTAT. For 2022 the changes Jan 2022-Dec 2022 last FOI index without tobacco published by ISTAT have been added.

98 European Commission (2018), Synthesis of the European Road Safety Observatory on post-accident relief.

between the accident and the arrival of emergency medical services from 25 to 15 minutes could decrease fatalities by a third[99].

For this reason, the **European Union** has introduced the mandatory presence of the **eCall safety device in every new car and commercial vehicle model approved for sale on the European market from 2018,** with the possible extension of its application to other vehicle categories. The eCall system is an emergency call that can be made manually by vehicle occupants via a button (e.g., the SOS button) inside the car or automatically activated by on-board sensors in the event of a serious traffic accident. When activated, the on-board eCall device generates an emergency call that transmits both voice and basic data (the exact location, time of the accident, vehicle identification number and direction followed) directly to the nearest emergency center[100].

In addition, innovative systems are being investigated to transport injured persons more quickly to rescue facilities or to bring medical assistance to the scene of the accident more quickly, e.g. by means of drones.

According to a Kearney study, the use of telematics and sensors connected with 5G could lead to a 30% reduction in road accidents[101].

Better traffic management and 5G data exchange between cars will lead to a reduction in accidents, but **according to a report by the European Commission, this will only lead to a 5% reduction in road accidents**[102].

Considering the number of accidents with injuries occurring in urban areas[103], the number of deaths caused by these accidents and the number of injuries caused by the same accidents, we attributed to each event a value such as that estimated by the Italian Ministry for Infrastructure and Transport (MIT) in 2010[104], revalued at current prices[105]. We added the resulting data and applied the prudential 5% reduction percentage due to 5G as already mentioned.

5G data capabilities and IoT technologies will reduce the number of road fatalities by more than 300 deaths and more than 39,000 injuries in road accidents on urban roads in the years 2023-2027 while reducing accidents with injuries by about 30,000 occurrences. This

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[99] Sánchez-Mangas, García-Ferrer, de Juan, Arroyo (2010), 'The probability of death in road traffic accidents. How important is a quick medical response?", Accident Analysis and Prevention (2010)

[100] https://europa.eu/youreurope/citizens/travel/security-and-emergencies/emergency-assistance-vehicles-ecall/index_it.htm

[101] Kearney. 2016. L'Internet of Things: un nuovo percorso verso la prosperità europea

[102] Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe, EC-2016

[103] Incidenti stradali - Year 2021, ACI-Istat

[104] Costi Sociali dell'Incidentalità Stradale – Anno 2019, Ministero delle Infrastrutture e dei Trasporti - dipartimento per i trasporti, la navigazione ed i sistemi informativi e statistici - Direzione Generale per la Sicurezza Stradale

[105] Elaboration Centro Studi TIM based on historical series "Il Valore Della Moneta in Italia dal 1861 al 2021", ISTAT, and for 2022 on the change from December 2021 to December 2022 of the latest FOI index without tobacco published by ISTAT.

will **reduce the overall cost of road accidents by about 3 billion euros cumulative to 2027, including about 577 million euros in 2027 alone**.

The urban environment: air quality

The vast majority of European citizens live in an urban environment, with over 60% of the population living in urban areas with more than 10,000 inhabitants. This means that daily life takes place in the same areas and the same mobility infrastructure is shared.

Urban mobility accounts for 37% of all CO2 emissions from road transport[106] and up to 70% of other pollutants from transport[107].

As we have already mentioned, European cities face more and more problems caused by transport and traffic. The question of how to improve mobility while reducing congestion, accidents and pollution is a common challenge for all major European cities. Congestion in the EU is often found in and around urban areas and costs almost 100 billion euros or 1% of EU GDP every year[108].

Finding answers to these challenges should be one of the main objectives of local governments. Efficient and effective urban transport can significantly contribute to the achievement of objectives in a wide range of policy areas for which the EU has established competence. The success of policies and policy objectives agreed at EU level, e.g., on the efficiency of the EU transport system, socio-economic objectives, energy dependency or climate change, depends in part on actions taken by national, regional, and local authorities. Mobility in urban areas is also an important facilitator for growth and employment and for sustainable development in EU areas.

Clean air is also essential for the health of citizens: the European Environment Agency estimates that almost 250,000 deaths in the EU in 2020 were attributable to exceeding the WHO-recommended PM2.5 values and that 96 per cent of the European population is exposed to values above these thresholds[109].

According to monitoring by the European Environment Agency, premature mortality due to air pollution in Italy in 2020 resulted in more than 68,000 premature deaths from

[106] *http://ec.europa.eu/transport/themes/strategies/doc/2011_white_paper/white_paper_working_document_en.pdf*
[107] *https://ec.europa.eu/transport/themes/urban/urban_mobility_en*
[108] *https://ec.europa.eu/transport/themes/urban/urban_mobility_en*
[109] *https://www.eea.europa.eu/publications/zero-pollution/health/air-pollution*

excessive exposure to air pollutants such as particulate matter, especially PM2.5 (52,303 deaths), nitrogen dioxide NO2 (11,158 deaths), and tropospheric ozone or O3 (5,077 deaths)[110].

According to Legambiente, Italy is in a chronic air pollution emergency, and the data on daily exceedances of the legal limits for PM10 in 2020 highlight this fact: out of 96 for which data are available, there are 35 cities in which at least one monitoring station exceeds the daily limit for particulate matter (set at 35 days in a calendar year with a daily average of more than 50 micrograms per cubic meter (µg/m3). Eleven cities had more than twice as many days in which the limits were exceeded[111].

In 2021, the year of recovery after Covid-19, the situation did not improve; on the contrary: partly owing to the climate, 2021 was one of the least rainy and hottest years in the history of weather surveys in Italy. Of the 102 cities for which data were available, only five were within the parameters set by the WHO for PM10, with a necessary reduction in dust concentrations for the other cities estimated at around 33 per cent, in order to be within the more stringent WHO limits. For PM2.5, the finest part of particulate matter and the one of greatest health concern, the national target for reducing concentrations was as high as 61 per cent, as none of the cities analyzed were within the WHO's suggested values. While for NO2, the reduction target was to be 52 per cent as only five cities were within the WHO parameters[112].

In the report “Mal'aria 2022” autumn edition, which analyzed the trend for the first 10 months of 2022, Legambiente showed that the situation had not improved. In the dossier, which examined 13 cities, nine of which are chief towns of the report selected to participate in the European Mission for Climate Neutrality by 2030, it was highlighted that no city on average met the WHO's recommended value for health protection for PM10 (15 µg/m3), for PM2.5 (5 µg/m3) and for NO2 (10 µg/m3), beyond the numerous exceedances of the threshold that represent the most acute moments of a chronic situation[113].

The latest update confirms the situation. In 2022, 29 cities, among those for which data are available, exceeded the 35-day limit for PM10 exceedances[114].

The days when PM10 levels are exceeded are a warning sign of smog, while annual averages of PM10 indicate the persistence of pollution and are the criterion for health protection, as stated by the World Health Organization guidelines that set 20 µg/m3 as the maximum annual average for PM10. European legislation currently sets 40 µg/m3 as the

[110] *https://www.eea.europa.eu/themes/air/country-fact-sheets/2022-country-fact-sheets/italy-air-pollution-country*
[111] *Mal'Aria di città r, 2021, Legambiente*
[112] *Mal'Aria di città, February 2022, Legambiente*
[113] *Mal'Aria, verso città mobilità zero emissioni, October 2022, Legambiente dossier produced as part of the European Clean Cities campaign.*
[114] *Mal'Aria di città, cambio di passo cercasi, January 2023, Legambiente dossier produced as part of the European Clean Cities campaign.*

maximum annual average for PM10, but this will be reduced to 20 µg/m3 from 2030. In 2022, 72 Italian cities, out of the 95 for which data were available, recorded an annual average higher than the WHO [115] recommended limit for air pollution. This represents 76% of the analyzed sample.

Also, for PM2.5 of the 85 cities for which data were available, as many as 71 (84% of the sample) recorded values in 2022 that were higher than those envisaged for 2030 by the next directive (10 µg/m3[116] versus 25 µg/m3). For nitrogen dioxide (NO2), the new limit of 20 µg/m3 (valid from 2030) would have been exceeded by the concentrations recorded in 2022 by 57 out of 94 cities (61%), which, however, did not exceed the current legislative limit[117].

The European Commission has initiated two infringement procedures against Italy for failing to comply with the regulatory limits established by the European Directive for PM10 and nitrogen oxides. In addition, a new letter of formal notice from the European Commission was sent in November 2020 regarding the excessive concentrations of fine particulate matter (PM2.5), as the measures adopted by our country to reduce these critical issues as quickly as possible were considered 'insufficient'.

This is despite the fact that, according to the Italian Institute for Environmental Protection and Research, ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale), greenhouse gas emissions have decreased steadily from 1990 (base year) to 2019 (-19%), **from 519 to 418 million tons of CO2 equivalent** (2019 figure, -2.4% year on year[118]). The decrease is attributable to the growth in recent years of power generation from renewable sources (hydro and wind), increased energy efficiency in industrial sectors, and a reduction in the use of coal. Despite improvements in the composition of energy generation, the power generation and transport sectors still account for about half of national climate-changing gas emissions.

It should be noted that transport, on the other hand, shows an increase in its weight of 3.2 per cent compared with 1990, reflecting the trend observed in fuel consumption for road transport, which shows an increase in total mileage (vehicle-km) of around 22 per cent over the reporting period[119].

The lockdown and restrictions imposed by the Covid-19 pandemic also had an impact on greenhouse gases. In fact, according to ISPRA's preliminary estimates, there were 9.8%

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[115] *Mal'Aria di città, cambio di passo cercasi, January 2023, Legambiente dossier produced as part of the European Clean Cities campaign.*

[116] *Micrograms per cubic metre (µg/m3).*

[117] *Mal'Aria di città, cambio di passo cercasi, January 2023, Legambiente dossier produced as part of the European Clean Cities campaign.*

[118] *National Inventory Report 2021, ISPRA*

[119] *National Inventory Report 2021, ISPRA*

fewer Co2 emissions in 2020 than in 2019, with a drop of as much as 16.8% in the transport sector.

Phasing out 'conventionally fuelled' vehicles from the urban environment[120] is one of the factors that can contribute most to reducing oil dependency, greenhouse gas emissions and air and noise pollution. This will have to be complemented by the development of adequate recharging/refuelling infrastructure for new vehicles.

Reducing congestion in cities would have various positive consequences. Faster travel would lower fuel consumption (both hydrocarbon and electric). This would result in fewer vehicle emissions and less pollution in general and from CO2. We envisage the '15-minute city', but also improvements in transport planning and the development of transport in a multimodal way, which would be enabled by more data availability and accessibility for administrations and citizens. Better access to information and communication would encourage more car sharing (including short-term vehicle rental and commuter travel sharing) and thus better optimisation of car resources in cities.

Connected and automated driving technologies will significantly improve traffic flows, reduce the incidence of critical situations, optimise the management of corresponding scenarios, relieve pressure on drivers and the environment, and support employment and growth.

In short, they will enable clean and CO2-reducing transport, a better living environment, especially for those suffering from asthma and bronchial diseases.

The extra time spent in the car due to traffic is estimated for Italy at an average of 24 per cent, with about 37 hours per person per year lost in traffic (worse than us in Europe are only Belgium and the United Kingdom, with 38 and 46 hours lost respectively), according to the annual ranking made by Tomtom's research centre[121] on more than 400 cities around the world. Again, Covid-19 helped, lowering the time lost in traffic in 2020 by about 50 per cent, while the first months of 2020 were in line with previous years[122].

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[120] *The term 'powered by conventional fuels' refers to vehicles using non-hybrid internal combustion engines.*
[121] *https://www.agi.it/data-journalism/tempo_perso_traffico-6074418/news/2019-08-26/#:~:text=Precisely%20we%20lost%2037%20hours%20in%20the%20absence%20of%20congestion.*
[122] *https://www.tomtom.com/en_gb/traffic-index/italy-country-traffic*

The benefits of IoT and 5G

The economic damage caused by an additional ton of carbon dioxide emissions – often referred to as the 'social cost' of carbon – has been estimated at 32 euros per ton of CO2 by the US Environmental Protection Agency (EPA) (37 dollars per ton), but subsequent research by a Stanford University team put this at as much as 197 euros per ton of CO2 (220 dollars per ton)[123]. This damage is expected to take various forms, including decreased agricultural yields, damage to human health and reduced worker productivity, all of which are linked to climate change. The US National Academies of Sciences, Engineering and Medicine (NAS) in 2017 published a report that updated the EPA's 'social cost of carbon' (SCC) estimates. According to the NAS report, the social cost of CO2 is about 40 dollars per ton of CO2 emitted in 2015, but could range from 12 dollars to 62 per ton, depending on climate change scenarios and risk assessments. The report also suggested that the social cost of CO2 should be regularly reassessed and updated based on new scientific knowledge and evolving climate policies[124].

The Social Cost of Carbon Initiative[125] by RFF - Resources for the Future[126], established to improve the scientific basis of SC-GHG (social cost of greenhouse gases), published in September 2022 an estimate of SC-CO2 at 185 dollars per metric ton of CO2[127]. However, in January 2023 the RFF itself recognized the EPA's[128] (Environmental Protection Agency's) study as the most reliable on the topic. The EPA sets the social cost per metric ton of CO2 at a range of 120 to 340 dollars for the year 2020[129], with increasing values until 2080.

According to a 2019 research[130], traffic management technologies could reduce CO2 emissions by 15-20% on average worldwide, saving between 3 and 5 gigatons of CO2 emissions by 2050.

In particular, the report emphasizes that optimizing traffic flow through the use of intelligent traffic management algorithms, promoting sustainable forms of mobility such

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123 https://news.stanford.edu/news/2015/january/emissions-social-costs-011215.html
124 Valuing Climate Changes, 2017, NAS
125 Established in 2017 as a multi-institutional collaborative effort between RFF and UC Berkeley, with additional contributors from Duke University, Harvard University, Princeton University, and the University of Washington
126 Resources for the Future is an independent, non-profit research institution in Washington, DC.
127 The study published in the peer-reviewed journal Nature in September 2022 (Rennert et al. 2022) used GIVE, developed by Rennert et al. 2022, to produce SC-GHG estimates for other emission years and for the other two main GHGs: methane and nitrous oxide, all available at https://www.rff.org/publications/data-tools/scc-explorer /
128 https://www.rff.org/publications/testimony-and-public-comments/updated-estimates-of-the-social-cost-of-greenhouse-gases-for-usage-in-regulatory-analysis/
129 page 81 EPA External Review Draft of Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances, 2023, https://www.epa.gov/system/files/documents/2022-11/epa_scghg_report_draft_0.pdf
130 Urban Mobility System Upgrade, World Economic Forum, 2019

as car sharing and bike sharing, and encouraging the adoption of low-carbon vehicles can significantly contribute to the reduction of CO2 emissions in urban transport.

If we consider the percentage attributable to road movements in urban areas of the 418 million tons of CO2 generated in Italy in a year (the percentage of CO2 production due to vehicles is 23.3%[131], generated in urban areas 37%[132]), we see how much of this CO2 is attributable to excess time spent in traffic (24%)[133], and if we apply the lowest value in the range of the benefit we can achieve by adopting intelligent traffic management systems (i.e. 15%), we calculate that we can save the generation of almost 1.3 million tons of CO2 per year.

To assess the influence of 5G and IoT in this environmental optimization process, we considered 5G's dynamic data exchange capabilities from sensors to be responsible for half of the reduction in congestion[134], amounting to approximately 650,000 tons of CO2 per year.

Considering the minimum value of the range estimated by the EPA for the years 2023–2027 as the social cost per ton of CO2, 5G and IoT functionalities could provide environmental benefits, through the reduction of traffic congestion in Smart Cities, of 84.5 million euros in the year 2027, with a cumulative saving of approximately 405 million euros[135].

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[131] *Le emissioni dal trasporto stradale in Italia, ISPRA 2019*
[132] *http://ec.europa.eu/transport/themes/strategies/doc/2011_white_paper/white_paper_working_document_en.pdf*
[133] *5G Impact Europe_EC*
[134] *5G Impact Europe_EC*
[135] *Euro/USD exchange rate of December 2022*

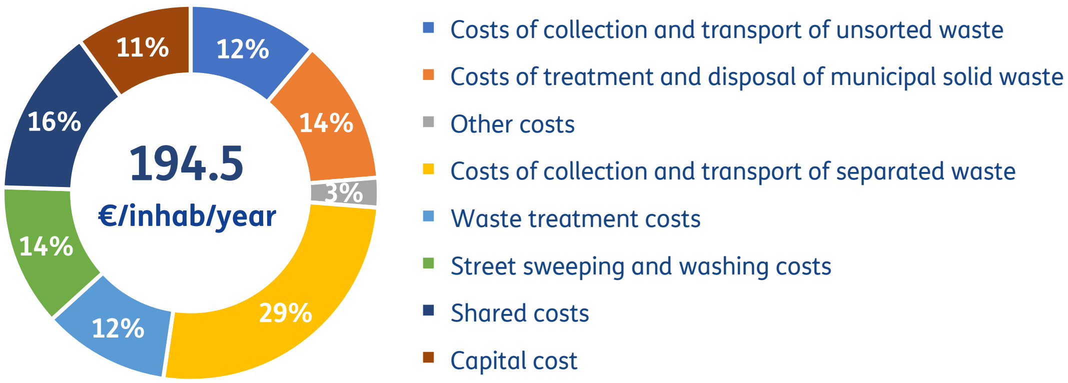
The urban environment: waste cycle management

The management of Municipal Solid Waste (MSW) is a critical activity that has economic, environmental, and social implications.

In 2021, 29.6 million kg of MSW was produced in Italy, i.e. each inhabitant produced an average of 502.1 kg of MSW, with a differentiation rate of 64 per cent[136]: the challenge today is to manage its separation, collection, treatment and disposal in an increasingly efficient manner.
At an Italian level, the cost of managing MSW from undifferentiated and differentiated collection is similar, but if we break down the costs, we can see that differentiated collection is more expensive than undifferentiated collection.

Specifically, the management cost of undifferentiated waste consists of 15.8 per cent of treatment and disposal costs, 13.3 per cent of collection and transport costs and 2.5 per cent of other costs; the management cost of differentiated waste, on the other hand, consists of 23.8 per cent of collection costs and 8.3 per cent of treatment and recycling costs[137].

Detail composition MSW costs per inhabitant[138]



The need for a different vehicle for each type of waste strongly affects the higher cost of collection and transport, so the lack of route and collection optimization is a major factor. Each administration is required to meet increasingly stringent targets aimed at reducing overall waste generation, increasing recovery, and recycling, and increasing sustainable disposal methods. These changes will be driven by the development of the Internet of Things and circular economy and Smart City models.

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[136] *ISPRA Urban Waste Report 2022*
[137] *ISPRA Urban Waste Report 2022*
[138] *Elaborations Centro Studi TIM on ISPRA Report Urban Waste 2022*

Waste management can be associated with an 'inverted pyramid' (or hierarchy) that orders the different waste treatment methods based on the level of sustainability associated with the different layers. In particular, Article 4 of the 2008 European Directive on Waste Framework outlines five priority levels of waste prevention and management legislation and policy to be applied by member states in order to encourage the options that give the best overall environmental outcome[139]

#1 **Prevention:** avoiding or reducing waste generation

#2 **Preparing for reuse:** checking, cleaning, repairing, or refurbishing waste items

#3 **Recycling:** turning waste materials into new products (e.g. composting)

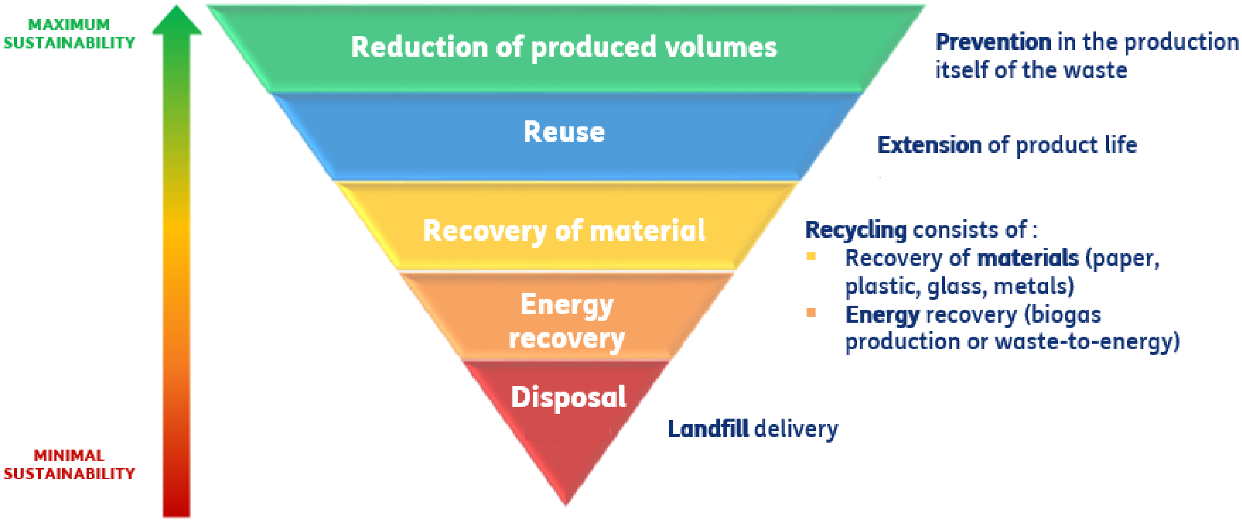
#4 **Other recovery:** recovering energy from waste through incineration or anaerobic digestion (AD)

#5 **Disposal:** landfilling or incinerating waste without energy recovery

The five layers of the pyramid correspond to these five options, which have different levels of sustainability. The lower the layer, the less sustainable the option is.

[139] *Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008*

The 'inverted pyramid' of different waste management methods[140]



The logic of waste planning at the European level, as outlined above, is based on the recognition that waste generation and its management (including landfilling and recovery through recycling) constitute one of the most significant and urgent problems to be tackled (both in terms of importance and complexity) in the environmental field. This is within a sustainable development strategy, defined by the well-known Brundtland report (1987) as that form of development which "meets the needs of present generations without compromising the ability of future generations to meet their own needs". The report proposes a four-step hierarchy for waste management:

- Minimizing production
- Maximizing material recovery
- Maximizing energy recovery
- Minimizing landfilling

Waste prevention (or reduction) is defined as "using less material to get a job done" or "that set of design, technological and organizational actions that allow the reduction of waste formation per unit of product (or more correctly, per unit of functional service)". By minimizing the waste that enters the production and consumption cycle, waste prevention is able to reduce the environmental impacts related to the entire non-produced waste management chain, starting from the reduction of impacts deriving from the collection,

[140] *Il ruolo chiave delle multiutility per il rilancio sostenibile dei territori italiani, The European House - Ambrosetti, 2020*

transport, treatment, recovery and final disposal phases. Waste prevention can also save money spent on waste disposal and conserve natural resources.

Some examples of waste prevention methods are: improving product design to use less materials, redesigning packaging to eliminate excess material, purchasing products in bulk, reusing products and packaging, and donating or exchanging surplus and reusable items.

The use of digital systems enables TAP or punctual pricing. This pricing system:

- is one of the most suitable tools for ensuring the proper implementation of the European waste management hierarchy, from prevention to disposal
- fully adheres to the European principles of 'polluter pays' and 'pay for what you throw away (PAYT - 'Pay-As-You-Throw')'
- relies on waste production detection and quantification systems that refer to each individual user serviced
- employs sustainable waste management solutions to achieve the aim of reducing municipal waste production

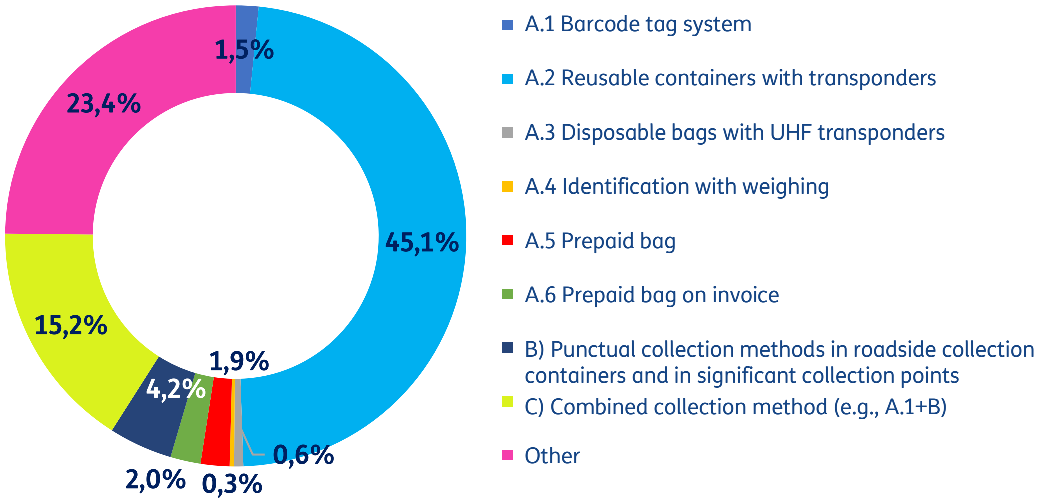
The ISPRA survey shows that 1,198 Italian municipalities adopted the punctual pricing (TP) system for municipal waste management service in 2021, with a total population of 8,268,861 inhabitants. This represents 15.0% of all Italian municipalities and 14% of the national population respectively (Census ISTAT 2021).

Municipal size matters: only 12 have between 50,000 and 150,000 inhabitants, and only 2 have more than 150,000 inhabitants.

The approaches vary, but they all rely on different technological forms that allow both the measurement of the waste quantity and its attribution to the individual, as well as separate collection. There is also cost reduction: the yearly cost per inhabitant was 180.5 euros (instead of 194.5 of the national average) [141].

[141] *ISPRA Rifiuti Urbani 2022*

Type of collection in municipalities with punctual charging, year 2021[142]



According to a study by Frost & Sullivan[143], a research and consulting firm, there are five digital transformations related to the use of new technologies in Smart Cities that are set to create new opportunities for the waste recovery and recycling sector, and that could generate 3.6 billion dollars in revenue globally:

1. The use of waste tracking systems, for example, through RFID systems and IoT sensors that can monitor the fill level of bins, the volume of materials and the quantities of paper, glass, plastic, and others that are being recycled.
2. The development and adoption of smart solutions such as smart bins, smart waste trucks, robotics, apps, analytical tools and software.
3. The development of innovative business models based on servitization (Everything as a Service - XaaS).
4. Focusing on the consumer and their customer experience in order to build a close and interactive relationship with their citizens and involve them more actively in the waste collection, recycling and management process.
5. The adoption of customized tools and funds to drive demand for data analytics, Internet of Things technologies and the use of cloud computing.

[142] *Report ISPRA Rifiuti Urbani 2022*
[143] *The Impact of Digital Transformation on the Waste Recycling Industry, Frost&Sullivan, January 2018*

The digital revolution is also set to change waste management services, a crucial area for a Smart City that aims to be sustainable and efficient, as well as digital. Connected bins and smart bins, smart solutions for waste logistics management, smart devices at disposal and recycling plants, cloud systems for collecting and processing data on waste collection operations.

The three distinctive elements that have an impact on collection costs and produce significant savings for operators, public administrations and citizens are:

SMART BIN

- IoT-connected devices and Big Data technology will have a crucial role in the future of waste management. The Smart Bin is the most prominent example of a Smart Waste Management infrastructure at present.
- The Smart Bin is a connected device with powered sensors that measure container usage and promote sustainable waste management. The sensors monitor various aspects such as filling, leachate production, temperature, movement, emptying, battery level.
- It can be either a specially designed container or a conventional container fitted with sensors.

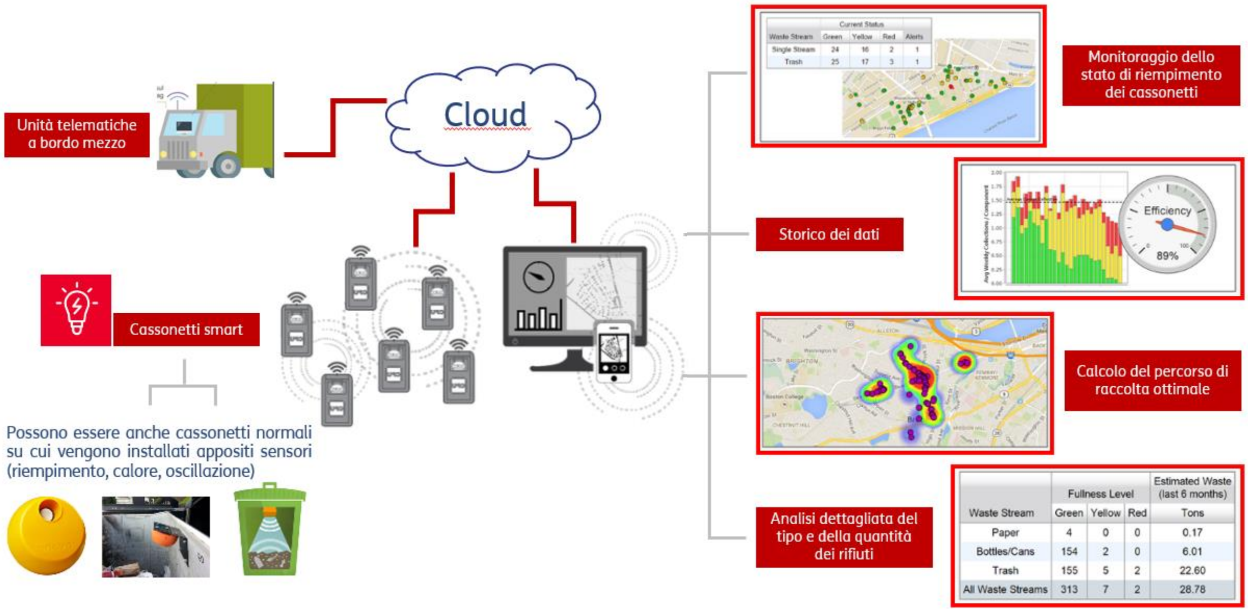
OPTIMIZING THE COLLECTION PATH (Fleet management)

- Smart Bin communicates with monitoring systems run by municipalities and waste management companies. This allows waste collection routes to be arranged to maximise container capacity and minimise the amount of street waste.
- Informed route planning also offers other advantages, such as lower fuel expenses for waste management companies and shorter working hours for staff.
- Furthermore, from a Smart City point of view, routes can be input into a control room platform, so that they can be adjusted according to urban traffic conditions.
- Many cities, such as Singapore, Dubai and Hong Kong, have already adopted this technology. The main players are usually private sector firms.

ASSET MANAGEMENT

- Smart Bin technology can also educate the public on the significance of recycling. Sensors that sense human touch activate information screens that encourage correct recycling to bystanders.
- Furthermore, by gathering data on the frequency of container emptying, households and municipalities can increase their awareness of waste, facilitating a better comprehension of how they can diminish waste production and support sustainable results.

Example of Waste Management in Smart City logic[144]



Solutions implemented in practice led to a 50% reduction in waste collection and management expenses. Given that the costs of collecting and transporting waste generated in Italy in 2021 amounted to nearly 4.3 billion euros, one can appreciate the effect that optimizing collection and transport routes with sensors and 5G networks can have on the waste industry.

The premise is that 5G's dynamic data-sharing abilities could account for half of the decrease in collection expenses.

Starting from the detailed composition of the costs for each MSW, we calculate that the cost of collecting differentiated and undifferentiated waste is about 4.27 billion euros[145] per year. However, we consider only the residents of urban areas (thus excluding those of rural areas, which are 24.5% of the population[146]), so the cost of collecting and transporting differentiated and undifferentiated MSW is about 3.25 billion euros in 2021[147].

Efficiency in the system can save about 1.6 billion euros per year. From these, using the share of efficiency related to 5G in logistics (equal to 2%[148]), it can be deduced that the impact of 5G and IoT affecting the reduction of waste transport and collection costs in 2027 will be almost 32 million euros (for a cumulative saving over five years of about 160 million euros).

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[144] *Elaboration Centro Studi TIM on various data*
[145] *Reference year 2021, TIM study center elaborations on ISPRA and ISTAT data (for population)*
[146] *ISTAT, 2021*
[147] *Reference year 2021, TIM study center elaborations on ISPRA and ISTAT data (for population)*
[148] *5G Impact Europe_EC*

The urban environment: light pollution

The phrase 'light pollution' denotes the unwanted or excessive artificial light that affects human health, wildlife behavior, and the ability to observe stars and other celestial objects. The main source of light pollution is unshielded light fixtures that scatter some of the light stream upwards, creating a phenomenon known as 'skyglow'. This has become more prevalent as urban and industrial areas have expanded.

The light emitted by streetlamps, buildings, signs, vehicles, boats, fireworks, and other artificial sources is scattered in the sky by particles in the atmosphere. This phenomenon causes the skies of some cities to be brightly lit even after sunset. It reduces the visibility of celestial objects: in the most polluted areas of the world, such as Singapore and Kuwait, 99.5 per cent of the stars are hidden. Light pollution mainly affects urban areas, but not only. In fact, even a small town can brighten the sky tens of kilometers away.

The phenomenon can be classified into four categories:

- Urban glow is the luminous halo that appears overpopulated areas at night. It is caused by particles in the air that reflect light;
- Light trespass occurs when light rays are scattered in areas outside the intended area of illumination. For example, this happens when the light from a streetlamp illuminates a neighboring garden;
- Glare is the brightness given by lighting fixtures that emit light horizontally;
- Over-lighting is the use of lights where they are not necessary, e.g. in vacant buildings.

Light pollution harms both wildlife and humans, partly by affecting melatonin[149] levels. Around 80 per cent of people worldwide, and 99 per cent of Europeans, live in areas affected by light pollution, which has serious implications for their health. Two recent studies in the journal Science report that light pollution increased considerably between 2011 and 2021, by 6.5 per cent annually in Europe and 10.4 per cent in North America: these rates are higher than those suggested by satellite data from different researchers[150].

To limit light pollution, we can take measures not only in cities but also in homes. The general rule is to use as little illumination as possible, but there are also other specific solutions:

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[149] *Artificial Light at Night: State of the Science 2022, International Dark-Sky Association*
[150] *Citizen scientists report global rapid reductions in the visibility of stars from 2011 to 2022, Kyba et al., Science Jan 2023, https://www.science.org/doi/10.1126/science.abq7781 and Light pollution is skyrocketing, F.Falchi and S. Barà, Science Jan 2023, https://www.science.org/doi/10.1126/science.adf4952*

- Choose low-temperature LEDs or sodium lamps, which are among the most efficient available, preferably in warm colours. At night, it is recommended to use red lighting, which interferes less with the body;
- Use motion sensors, timers or other devices to switch off outdoor lights when they are not needed;
- Turn off lights in buildings, especially at night. It is advisable to turn them off one hour before bedtime for good sleep hygiene;
- Prefer low-temperature LEDs or sodium lamps, among the most efficient available, preferably in warm colors. At night it is recommended to use red lighting, which interferes less with the body;
- Use curtains to block light from escaping outside the house in the evening. This also reduces bird collisions with glass.

Many cities have adopted a lights-off program for the evenings when birds migrate, and more and more countries are implementing solutions to reduce light pollution. Sustainable lighting is also one of the UN's 2030 Agenda sustainable development goals, which estimates that we would save 120 billion dollars every year if we used more efficient light bulbs worldwide.

In recent years, therefore, rules and regulations have been developed with the aim of limiting this dispersion phenomenon in public lighting and, more generally, in all outdoor lighting. Limiting the problem also means saving energy and thus money. In fact, since most artificial light is produced through the use of fossil fuels, reducing light pollution would also lead to less air pollution.

What is happening in Italy?

According to a study[151] published in 2019 in the Journal of Environmental Management, Italy is among the European countries with the highest amount of light used per person, along with Portugal and Spain. The research links light pollution to population density and GDP for the first time, creating a map that shows Central and Eastern European states as the most virtuous. Of the 1,359 European provinces in the ranking, only Naples, Bolzano and Genoa are in the top half, while as many as 58 Italian provinces are in the bottom half.

The Energy Services Manager (GSE) states that urban illumination accounts for 2 per cent of the country's energy use, and that public lighting is a major source of energy spending for local authorities, ranging from 20 to 30 per cent of their outlay.

[151] *F.Falchi, R.Furgoni, T.A.Gallaway, N.A.Rybnikova, B.A.Portnov, K.Baugh, P.Cinzano, C.D.Elvidge, Light pollution in USA and Europe: The good, the bad and the ugly, Journal of Environmental Management, Volume 248, 15 October 2019, 109227*

Italian consumption of public lighting was largely unchanged from 2007 to 2019 (about 6,000 GWh in 2007), but dropped to 5,146 GWh in 2020, presumably because of the pandemic crisis. Italian spending on public lighting increased from 1.7 billion euros in 2017 to 1.8 billion in 2019. In 2016, Italy's per capita spending on public lighting was 28.7 euros, much more than the main European countries' average (16.8 euros), France (20.3 euros), the United Kingdom (14.2 euros) and Germany (5.8 euros) [152]. A similar pattern emerged in 2019, with Italy's per capita spending on public lighting at 30.5 euros, far above Austria (24.6 euros), France (22.7 euros) and Germany (4.8 euros). Meanwhile, according to the Observatory on Italian Public Accounts (Osservatorio CPI), Italy's per capita electricity use for public lighting is double the European average[153].

There are approximately 10 million public lighting points in Italy, of which over half are obsolete or substandard, roughly one for every six people[154]. This results in four million tons of CO2 emissions annually[155]. The study estimates that upgrading the entire inventory of streetlights would require 3 billion euros.

In recent years, around 60 per cent of Italian municipalities have switched from sodium lamps to Light Emitting Diodes (LED) bulbs in streetlamps. LEDs are currently the most efficient sources because they can transform more than 50 per cent more electrical power (watts) into light (lumens) than sodium lamps, thereby considerably reducing both cost and electricity consumption[156]. It is estimated that there are about 3.5 million LED streetlights in Italy[157] today. Replacing light sources with LED lamps is an energy efficiency measure that can cut consumption, and hence costs, by 40%-60%, especially when combined with modern technologies and innovations, such as remote control and motion sensors.

This entails increasing lighting power (and associated cost) when necessary, using motion sensors that can detect pedestrians or vehicles passing by (TAI, Traffic Adaptive Installation), or FAI (Full Adaptive Installation) sensors that combine traffic data with weather and ambient light levels to regulate installed LED lamps. Another option is to install remotely adjustable astronomical clocks in the switchboards that control the lighting points, so that the switch-on and switch-off times can be modified.

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[152] *Public lighting: we spend too much, by Carlo Cottarelli, Diego Bonata, Fabio Falchi, Riccardo Furgoni and Carlo Valdes, CPI Observatory - Catholic University of the Sacred Heart, May 2018*

[153] *LED: a solution for public lighting in Italy?, by Diego Bonata, Fabio Falchi, Luca Favero, Emma Rosenfeld, Alejandro Sanchez, Osservatorio Conti Pubblici Italiani (OCPI), June 2022*

[154] *GSE data*

[155] *https://www.engie.it/newsroom/news/come-migliorare-inquinamento-luminoso/#:~:text=11%20million%20of%20light%20points%20for%20public%20lighting%20in,%25%20of%20energy%20per%20year.*

[156] *LED: a solution for public lighting in Italy?, by Diego Bonata, Fabio Falchi, Luca Favero, Emma Rosenfeld, Alejandro Sanchez, Osservatorio Conti Pubblici Italiani (OCPI), June 2022*

[157] *https://www.cogeserenergia.it/it/illuminazione-pubblica-10-milioni-di-punti-luce-in-italia-quanti-a-led*

Some of these measures, such as switching to adaptive street lighting (which, as previously stated, enables the level of street lighting and illuminance to be adapted to actual traffic situations, weather, and time of day, through dedicated sensors and cameras), have already produced significant results suggesting that the potential savings could be even higher, ranging from 60 to 80 per cent.

The deployment of LED streetlights has not yet achieved its full potential in reducing costs for two reasons:

- adaptive technologies with TAI or FAI-type sensors, which could offer more advantages, are not widely used in Italy;
- the reduced cost of LEDs has led to the installation of new lighting points, resulting in higher consumption.

There are also environmental issues. So far, only white, cold-light LED sources of 4000K or higher have been used almost exclusively. Warm LED sources, 3000K or lower, have nearly the same efficiency and much better light quality and eco-friendliness[158]. White LEDs actually cause more light pollution because they emit a lot of blue light, which affects the biorhythms of animals and humans.

To reduce costs and save energy, investment is needed. This involves modernizing installations and using LED streetlights, as well as other technologies such as motion and smart sensors, smart lighting systems, IoT devices, video cameras, and energy consumption monitoring systems.

Light poles can play a vital role in the Smart City by providing management savings when equipped with devices that monitor air quality and weather conditions, Wi-Fi connection systems, traffic control devices and parking management, and video surveillance systems for public safety. Smart lampposts can also protect historic buildings from collapse and potential earthquakes, detect smoke and prevent fires, and serve as charging stations for electric vehicles[159].

Greenlight[160] is an Anas S.p.A. project that aims to improve road lighting and energy efficiency on motorways, especially in tunnels. It involves replacing old light fixtures with new LED systems that have a point control system for adjusting them. Moreover, after the Smart Road Decree was published (April 2018), the Ministry of Infrastructure and Transport is promoting a new idea of smart roads that enable communication with vehicles by

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[158] *LED: a solution for public lighting in Italy?, by Diego Bonata, Fabio Falchi, Luca Favero, Emma Rosenfeld, Alejandro Sanchez, Osservatorio Conti Pubblici Italiani (OCPI), June 2022*

[159] *Public lighting: we spend too much, by Carlo Cottarelli, Diego Bonata, Fabio Falchi, Riccardo Furgoni and Carlo Valdes, CPI Observatory - Catholic University of the Sacred Heart, May 2018*

[160] *https://www.stradeanas.it/it/sostenibilit%C3%A0/i-principi-della-sostenibilit%C3%A0/tutela-dellambiente/energia#:~:text=The%20pluriennial%20project%20greenlight%20characterised%20by%20high%20energy%20efficiency.*

providing real-time information about traffic and potential accidents, monitoring weather conditions and road bottlenecks, managing access, parking, and refueling at service stations as well as facilitating emergency response. Anas is also conducting preliminary tests in this area. Anas S.p.A., part of the FS Ferrovie dello Stato Group, operates Europe's largest road network and manages more than 30,000 km of roads and motorways in Italy with over 6,000 employees.

Livorno, a Tuscan port city on Italy's west coast, is experimenting with a Smart City model that relies on the electricity grid and uses LED streetlights and traffic lights as smart poles with sensors and cameras. This requires a major overhaul and redefinition of public lighting. Livorno's renewal is part of the ES-PA - Energy and Sustainability for Public Administration[161] project by ENEA (Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile), an Italian public agency that aims to foster research, technological innovation, and sustainable economic development, and to provide advanced services in the energy sector, especially nuclear energy. The project uses technologies such as Big Data and the Internet of Things and hopes to create a urban model that can be replicated in other cities.

The benefits of IoT and 5G

The aim of this analysis is to replace conventional public lighting lamps with LED technology and smart lighting management. We project an initial saving of only 40 per cent, which could increase to 80 per cent of maximum efficiency over time. Our assumption is that all conventional sodium lamps will be substituted by LED lamps in a linear fashion from 2023 to 2027.

The project should cover the 6.5 million light poles that require upgrading. Nevertheless, this study only takes into account the urban ones. According to the percentage of people who reside in urban areas (large, medium, or small cities) as opposed to rural areas (24.5 per cent of inhabitants[162]), we are dealing with slightly more than 4.9 million light poles.

By implementing this replacement, more than 268 thousand MWh[163] would be conserved in the first year, resulting in a cost saving of about 97 million euros[164] and a reduction of CO2 equivalent emissions by over 74 thousand tons per year.

[161] *https://www.espa.enea.it/#:~:text=The%20Project%20ES%2DPA%20%E2%80%9CEnergy,administration%20and%20te chn ical%20of%20the%20public%20publics*

[162] *ISTAT 2021*

[163] *SOS MUNICIPALITY - Energy Emergency: Guidelines for Recalibrating Temporary Switching On and Off and Rationalising Street Lighting, https://cielobuio.org/sos-comuni-emergenza-energetica-linee-guida-per-ricalibrazione-accensioni-e-spegnimenti-temporanei-e-razionalizzazione-dellilluminazione-pubblica/*

[164] *The reference is the ARERA price per Kwh of 20 January 2023*

We also took into account an improvement in efficiency due to the adoption of adaptive street lighting systems like those mentioned above, so that at the end of the five-year period the saving values considered would match what was suggested as an assessment method for the European Enterprise Climate Cup[165], according to which the total consumption of an LED street lighting lamp is one-fifth of that of a conventional one.

Therefore, **in 2027 the savings would be approximately 2,000 GWh, corresponding to a saving of expenditure of approximately 726 million euros**[166], and **a saving of CO2 equivalent emissions of approximately 1.48 million tons**. The total savings over the five-year period would be 1.95 billion euros, while the cost of the operation would amount to approximately 2.3 billion euros.

Not taken into account are the differentiated and integrated uses of the Smart City that can be achieved by equipping lampposts with other sensors.

Sustainability impacts of IoT and 5G: summary

We have explored some of the main effects of related enabling technologies for the Smart City, especially those concerning IoT, LPWA and next-generation networks, such as 5G.

Our aim was to measure the benefits in economic terms and in terms of reducing CO2 emissions, with a view to achieving the goals set for our country and the EU as a whole by 2030 and 2050.

However, these are not the only advantages that can be obtained. In particular, when we consider systems such as Urban intelligence and Digital twin, we can see how the ability to model and evaluate alternative options, based on the data collected by the smart city, creates a win-win phenomenon. More data leads to better choices, which leads to greater efficiency, which leads to lower impacts, which leads to greater sustainability and better quality of life, and so on.

The benefits of using IoT, Urban Intelligence and AI systems are not yet clearly measured by any widely accepted systems.

We present a summary of the calculations that have been done based on various scientific studies and methodological proposals. These calculations aim to quantify the impact of these technologies on different aspects of urban life, such as energy efficiency, mobility, security, health, and social inclusion. The sources of these calculations are referenced at the end of this text.

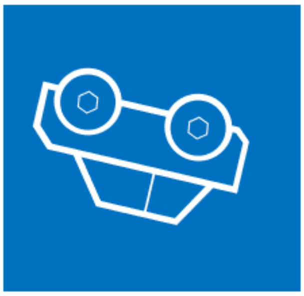
[165] *https://www.eceee.org/events/calendar/event/european-enterprises-climate-cup-2016/*
[166] *The reference is the ARERA price per Kwh of 20 January 2023*

Congestion cost of urban areas

Includes:

- Fuel costs
- Vehicle operating costs
- Monetary revaluation of time costs

Annual economic savings in 2027	Appx. 1.4 Bn €
Cumulative savings in 2023-2027	Appx. 6.5 Bn €



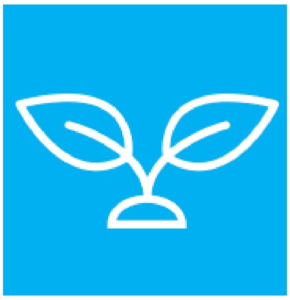
Costs of road accidents with injuries

Includes :

- Road accidents with injuries in urban areas
- Injured people in urban areas
- Deaths due to road accidents in urban areas

Reduction of 30,000 road accidents, 300 deaths and 39,000 injuries, in the years '23-'27

Annual economic savings in 2027	Appx. 577 Mn €
Cumulative savings in 2023-2027	Appx. 3 Bn €



CO2 savings from reduced traffic in urban areas

Approximately 430,000 tons of CO2 per year

Annual economic savings in 2027	85.5 Mn €
Cumulative savings in 2023-2027	405 Mn €

Waste collection costs

Includes:

- Optimization of collection routes

Annual economic savings in 2027	32 Mn €
Cumulative savings in 2023-2027	Appx. 160 Mn €

Street lighting costs

Includes:

- Replacement of traditional lamps with LED lamps
- Involvement of 4.91 million urban streetlights

First year savings of 268,000 MWh, equal to 72,000 tons of CO2-equivalent less

Annual economic savings in 2027	Appx. 726 Mn €
Cumulative savings in 2023-2027	Appx. 1.95 Bn €

Methodological note

The benefits of IoT and 5G on traffic congestion

The evaluation of the benefits of 5G on traffic congestion considers the following elements:

A. Estimate the value of the cost of congestion as 1% of the value of GDP
B. Estimated Italian GDP for 2022 from International Monetary Fund (IMF)[167], amounting to 1,889.3 billion euros
C. Congestion cost growth of 50% between 2013 and 2030 (source: Centre for Business & Economic Research (CBER) [168], i.e., CAGR 2.41%
D. Estimated congestion reduction as a benefit of using IoT technology of 10% (source: Kearney) [169]
E. Estimated 60% share of traffic congestion in urban areas (source: European Commission) [170]

The first year's benefit is then determined by multiplying AxBxDxE.

The benefits in subsequent years are estimated by increasing this initial value with the rate in C, which is 2.41% per annum.

The benefits of IoT and 5G on road accidents

The assessment of the benefits of 5G on road accidents considers the following elements:

A. Value of the accident as the external/social cost of death or injury (moral cost, medical cost and general cost of damages generated) in the accident with injuries. These unit costs were determined by the Italian Ministry of Infrastructure and Transport (Ministero delle Infrastrutture e dei Trasporti - MIT)[171] in 2010 currency:
    a. person killed in a car accident: 940,291 euros (loss of production) + 561,734 euros (moral suffering) + 1,965 euros (medical assistance) = 1,503,990 euros.
    b. person injured in a car accident: total cost (including loss of production, moral suffering, and medical treatment) is 42,219 euros.
    c. the overall cost of a claim is assumed to be 10,986 euros.
    d. These values were then discounted to 2022 according to the Italian National Institute of Statistics - Istat index (latest FOI index without tobacco). [172]

[167] *International Monetary Fund, World Economic Outlook Database, October 2022*
[168] *http://www.cebr.com/reports/the-future-economic-and-environmental-costs-of-gridlock*
[169] *The internet of things: a new path to European prosperity, January 04, 2016 https://www.middle-east.kearney.com/digital/article/-/insights/the-internet-of-things-a-new-path-to-european-prosperity*
[170] *5G Impact Europe_EC*
[171] *Costi Sociali dell'Incidentalità Stradale – Anno 2019, Ministero delle Infrastrutture e dei Trasporti - dipartimento per i trasporti, la navigazione ed i sistemi informativi e statistici - Direzione Generale per la Sicurezza Stradale*
[172] *Elaboration Centro Studi TIM based on historical series "Il valore della moneta in Italia dal 1861 al 2021", Istat, and for 2022 on the change from December 2021 to December 2022 of the latest FOI index without tobacco published by Istat.*

B. Number of accidents derived from the historical series in the Istat Road Accident Report 2021.
C. Estimation of the urban share of accidents, determined by classifying accidents by the type of road on which they occurred (urban roads, motorways and junctions, suburban roads) from the same report. This historical series shows an incidence rate on urban roads in the last five-year period 2017-2021 of 74% of total accidents, 43% of total fatal accidents, 70% of accidents with total injuries.
D. Number of accidents in the perspective years in trend from the historical series, showing a reduction in accidents (CAGR of -2.8% for accidents with fatalities, -2.6% for accidents with injuries, -2.3% for accidents with injuries).
E. Estimated accident reduction due to 5G at a conservative 5%, analogous to the reduction in traffic congestion.

The above parameters yield a cumulative benefit over the period 2023-2027 from the use of 5G, equivalent to a reduction of 313 deaths, 39,150 injuries and a lower social cost of approximately 3.04 billion euros.

The benefits of IoT and 5G on air quality

The assessment of the benefits of 5G on air quality considers the following elements:

A. CO2 produced in Italy by means of transport, amounting to 418 million tons.[173]
B. Share of transport vehicles in road vehicles alone, which is 23.3 per cent of CO2 emissions.[174]
C. Share of road mobility of vehicles in urban areas, which is 37 per cent.[175]
D. Share of such urban traffic related to time in excess of useful travel time, which is 24 per cent. [176]
E. Benefit of intelligent traffic management mechanisms in terms of percentage reduction of CO2 emissions caused by traffic congestion, ranging from 15 to 20 per cent[177], conservatively considered here as 15 per cent.
F. Share of this benefit from intelligent traffic management mechanisms attributable to 5G and IoT[178], which is 50 per cent.
G. 'Social cost' of carbon of 120 euros per ton of CO2.[179]

Multiplying the above parameters results in a benefit of lower CO2 emissions of 430 thousand tons due to 5G, equivalent to a lower annual social cost of 76.3 million euros.

[173] *National Inventory Report 2021, ISPRA*
[174] *Le emissioni dal trasporto stradale in Italia, ISPRA 2019*
[175] *http://ec.europa.eu/transport/themes/strategies/doc/2011_white_paper/white_paper_working_document_en.pdf*
[176] *5G Impact Europe_EC*
[177] *Urban Mobility System Upgrade, World Economic Forum, 2019*
[178] *5G Impact Europe_EC*
[179] *page 81 EPA External Review Draft of Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances, 2023, https://www.epa.gov/system/files/documents/2022-11/epa_scghg_report_draft_0.pdf*

The benefits of IoT and 5G on waste management

The assessment of the benefits of 5G on waste management considers the following elements:

A. Historical trend of the amount of annual municipal waste produced in Italy and the associated percentage of separate collection. [180]
B. Forecast of the amount of annual municipal waste produced and the associated percentage of separate collection by applying the respective historical compound annual growth rates (CAGRs) to 2021 values.
C. Unit costs per inhabitant for transport of separate and undifferentiated waste collection.[181]
D. Evolution of the number of inhabitants in Italy (source Istat) with projection according to historical trend.
E. Estimated collection and transport efficiency from analysis of the results of different field solutions of 50 per cent.[182]
F. Share of efficiency attributable to 5G equal to the share of efficiency due to 5G in logistics, that is, 2 per cent.[183]

Multiplying these parameters over the forecast years 2023-2027 yields a cumulative benefit of 5G on municipal waste collection and transport costs of 211.8 million euros.

The benefits of IoT and 5G on lighting costs

The evaluation of the benefits of 5G on waste management is limited to assessing the benefits of replacing conventional streetlamps with LED technology lamps.

The following elements are therefore considered:

A. Number of light poles still with conventional lamps: 6.5 million.[184][185]
B. Percentage of these light poles in urban areas: 75.5% (equal to percentage of the population in urban areas), i.e. 4.9 million light poles with conventional lamps.[186]
C. Working hypothesis: replacement with linear progression over five years of these poles (981 thousand poles per year).
D. Annual consumption of a conventional light pole: 683 kWh per year.[187]
E. Increased replacement efficiency, from 40% in the first year (2023) to 80% in 2027 (indicated value of replacement efficiency by the European Enterprise Climate Cup).[188]

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[180] *ISPRA Rifiuti Urbani Report 2022*
[181] *Elaborations Centro Studi TIM on ISPRA Report Rifiuti Urbani 2022*
[182] *Elaboration Centro Studi TIM on various data*
[183] *5G Impact Europe_EC*
[184] *GSE data*
[185] *https://www.cogeserenergia.it/it/illuminazione-pubblica-10-milioni-di-punti-luce-in-italia-quanti-a-led*
[186] *Elaboration Centro Studi TIM on urban population data Istat 2021*
[187] *Calculated on data in the "Guida emergenza energetica per i comuni" (Energy Emergency Guide for municipalities) at https://cielobuio.org/sos-comuni-emergenza-energetica-linee-guida-per-ricalibrazione-accensioni-e-spegnimenti-temporanei-e-razionalizzazione-dellilluminazione-pubblica/*
[188] *https://www.eceee.org/events/calendar/event/european-enterprises-climate-cup-2016/*

F. Grams of CO_2 produced per kWh consumed: 276.3g.[189]
G. Average cost per kWh consumed of 0.361 euros.[190]

The appropriate multiplication of these parameters calculates the lower consumption of kWh of energy for each year, and the associated lower production of tons of CO_2 and their respective values.

[189] *ISPRA ambiente "Fattori di emissione atmosferica di gas ad effetto serra nel settore elettrico nazionale e nei principali Paesi Europei" (Greenhouse gas emission factors in the national electricity sector and major European countries) ed. 2020*

[190] *ARERA: regulated kWh tariff as of 20 January 2023 in the protected market.*

CHAPTER 5

Security - the cameras

In recent years, video surveillance camera installations have been widely used in both the private and public sectors for various reasons, including the demand for public safety and the prevention of vandalism or crime.

In the private sector, the most immediate solution is intrusion detection systems integrated with video analytics, which offer high-level, automated surveillance, with real-time alarms and video of the event sent to the monitoring company or authority. This process allows the authorities concerned to provide rapid and accurate responses.

In Smart Cities, there are different types of applications, often linked to the adoption and development of Artificial Intelligence (AI) systems that enable significant events to be highlighted without constant monitoring.

Fixed road (e.g. on lampposts) or vehicle-mounted camera systems are used to perform different types of traffic anomaly detection. Applications include lane departure warning, pedestrian detection and adaptive warning systems.

In traffic management and surveillance, vehicle detection and tracking algorithms are used to identify specific incidents and events. Such systems are widespread in smart city applications, including for collecting traffic parameters, counting vehicles, video-based tolling, analyzing traffic flow and understanding behavior. Other use cases include accident detection, motorway vehicle detection and vehicle classification (profiling).

Vision-based vehicle identification uses automatic number plate recognition and detection of vehicle characteristics (color, type) to identify and count individual vehicles using cameras. The vehicle identification software first detects the vehicle using object detection, locates the number plate and then reads the number plate using optical character recognition.

Detection and tracking of moving vehicles or objects used in combination with number plate recognition and image classification algorithms are used in intelligent parking space analysis to identify and monitor the occupancy of multiple parking spaces by superimposing artificial views of spaces on real images.

Speaking more specifically about security, the identification of abnormal events that emerge through the examination of a city's live camera feeds can trigger preventive action against incipient fires, disruptive behavior, robberies and other emergencies such as traffic accidents, dangerous gatherings, threat detection (e.g. the presence of weapons), drowning and the detection of injured or fallen people, as well as widespread problems such as littering on the streets.

Visual surveillance can of course be performed by people in a control center, but, especially by increasing the number of cameras installed, it maximizes its efficiency by using modern AI vision systems, which integrate with almost closed-circuit television (CCTV) and video management system (VMS) monitoring systems.

Another critical aspect of security is the detection of abandoned objects. It involves the use of automated systems that can detect any object left in public or private areas without human intervention. A deep learning model can be trained to detect objects such as bags, boxes, parcels, and other items that could pose potential security threats.

Real-time surveillance will greatly contribute to the ability of municipalities to monitor incidents, crowd behavior, traffic patterns and other activities in public spaces. The immediate response to violations of social distancing and other preventive measures in the Covid-19 era has become a particularly significant aspect of live video surveillance.

Video surveillance is therefore an effective tool that can increase citizens' perception of security and can represent a concrete technological support capable of capturing images of a criminal event and identifying the perpetrators of crimes.

Video surveillance activity for municipalities is a delicate matter and must adhere to specific rules, to avoid the administration facing penalties that can be very severe in some cases: monitoring citizens' every move is a privilege and a right that many public administrations have by virtue of a higher interest in urban and public safety, but this cannot and must not be done at the expense of individuals' fundamental rights and freedoms. Therefore, let us see what standards and requirements must be met for a public video surveillance system to be legally compliant (and penalty-proof).

The Privacy Guarantor has issued a set of principles to protect private individuals who equip themselves with video surveillance services:

- Principle of lawfulness: video surveillance must comply not only with data protection regulations, but also with other regulations on the installation of audiovisual equipment;
- Principle of necessity: superfluous, excessive and redundant use of equipment must be excluded;
- Principle of proportionality: video surveillance systems may only be installed when other measures have been insufficient or impracticable;
- Purpose principle: the purposes pursued must be determined, explicit and legitimate.

Security

For public safety purposes, data processing through video surveillance is a prerogative of municipalities, which, according to Legislative Decree 11/2009, may use installations for the protection of urban safety in public places or places open to the public, i.e. filming streets and squares.

However, the rule must be coordinated with European Union Reg. 679/2016, the GDPR, European Regulation on Personal Data Protection, which has established a series of processing limits for the data controllers (the Public Administration that installs the device) and for the data subjects (the citizens), especially regarding retention periods, processing purposes and the technical requirements of the systems.

In essence, the municipality that decides to install a video surveillance system assumes all the responsibilities, agreeing to implement a legally risky activity (data processing) and obliging itself to put in place all the necessary technical and organisational measures, in accordance with the principle of accountability, which is the acknowledgement and assumption of responsibility for actions, decisions and their consequences, and the privacy by design, a principle established by the EU GDPR that stipulates the need to protect data from the design phase of the systems that collect and use them. This means that data protection should be integrated into the technology when it is created, rather than added later as an afterthought.

Furthermore, since public video surveillance systems also serve a security purpose in the strict sense, i.e. preventing and repressing crime, the Data Controllers (the Municipalities represented by their current mayors) may enter into special security pacts and also make the remote monitoring systems available to the State Police (Polizia di Stato), the civil national police, and Carabinieri (Arma dei Carabinieri), the national gendarmerie. In this particular eventuality, EU Directive 680/2016, transposed into our system by Legislative Decree 51/2018, a legislative provision that places exceptions to certain fundamental principles of the GDPR in favor of entities carrying out investigations in the field of urban security (including the Local Police), applies.

Before installing any video surveillance system with video or photo cameras, photo traps or any other tool suitable for filming citizens in public areas, municipalities must conduct an impact assessment. The impact assessment (D.P.I.A. - Data Protection Impact Assessment) required by Article 35 of the GDPR is a process that describes the processing, evaluates its necessity and proportionality and manages any risks to the rights and freedoms of individuals resulting from the processing. Moreover, they must adopt a municipal regulation specifically for this legislative decree to avoid the paradoxical situation of not being able to use the images from security cameras because they are installed in violation of regulations or contrary to GDPR.

The regulation must specify the retention policy; that is, how long the images will be kept and for what purposes they are collected. It must also identify the persons authorized to view the images (formally designated and specifically trained by the Data Controller, which is always the Municipality), not only generally with regard to the GDPR but also specifically with regard to the processing under consideration. If an external company is used, the appointment of an external data processor pursuant to Article 28 is mandatory. Finally, appropriate notices must be drawn up that contain the requirements of Article 13 of the Regulation.

A brief information notice is required that must be displayed in the video-surveillance area, also by means of posters. It must contain at least:

- The data of the data controller
- The purposes of the processing
- The retention periods
- The procedures for exercising the rights of the data subjects
- A reference to a full information notice that may be contained on, for example, the municipal website.

As for enforcement, as of June 2022, 71 per cent of the sanctions imposed by the Data Protection Authority since the GDPR came into force concerned public bodies. It was estimated that 92 per cent of cameras installed violated privacy regulations.[191]

Due to a lack of dedicated studies, it is not possible to quantify economically the impacts of using surveillance cameras with the associated AI systems for public safety purposes. However, it is certain that more and more public administrations and citizens are using this tool to improve the sense of security in cities, as the data on the most popular public projects presented earlier in this paper also show.

[191] *https://www.lagazzettadeglientilocali.it/la-videosorveglianza-nei-comuni-istruzioni-per-un-impianto-a-norma-di-legge-e-a-prova-di-sanzioni.html*

CHAPTER 6

Smart City Policy: Towards a holistic approach

Although the prospects in terms of solutions and impacts expected from the intelligent transformation of urban environments are now becoming quite clear, Smart Cities represent an ecosystem that is still under construction in many respects.

The actual realization of such a scenario does not depend solely on technological factors but requires the public decision-maker to govern the project of realizing a Smart City actively, and this almost always involves innovation in procedural, managerial, regulatory and bureaucratic terms in several areas.

Strategies and fields of application: favor a more horizontal approach, overcoming regulatory barriers and sectoral constraints

Installing sensors and making parts of 'street furniture' smart are important first steps in the realization of a Smart City. However, making sense of the data collected in a synergistic and meaningful way is an equally crucial challenge. As we have pointed out in the previous chapters, a Smart City presents itself as an articulated and complex ecosystem, on which several areas of application impinge, each with its own logic, processes, and modes of operation. Until now, each of these areas has mostly been treated as a vertical segment. Excessive fragmentation due to technical factors (e.g. different standards, unevenly collected data, etc.), which is also facilitated by regulatory aspects and bureaucratic delays, makes it almost impossible to design cross-sectoral solutions.

Several examples can be given in this respect:

As we have recounted in the dedicated chapter, all cities today are monitored by a dense network of video surveillance cameras for various reasons (security cameras, control of limited traffic zone entrances (ZTL), road traffic monitoring, video traps against the abandonment of waste in illegal dumps, etc.). This set of objects represents a vast network of observation sensors that, with the support of artificial intelligence algorithms, could provide data to the system that triggers the necessary actions (e.g. requests for security interventions, reorganization of traffic light system timings, etc.) in a much shorter time than human reaction with considerable positive effects (consider the need for rapid or preventive security interventions or the need to make city traffic flow more smoothly as vehicles circulate at different times of the day). This development trajectory is also complicated today by the different regulations on data retention (limited to 24 hours for some types of use, for longer periods in others).

Smart objects require a **power supply**, and this necessity can cause a slowdown in setting up sensor networks in areas that are not served by the electricity utility's distribution network. This can also vary from one municipality to another because of different local regulations governing the installation of power lines. Some of these needs can be overcome by using technologies and networks that are already in place, such as telecommunication infrastructures that have a ubiquitous network that can be used as a framework to support Smart City services or Low Power Wide Area Networks.

Moreover, moving to a more transversal and less sectoral design system may highlight any missing 'pieces' in the mosaic:

Increased energy efficiency will undoubtedly be one of the positive effects of a Smart City, both in terms of energy saved through the optimal management of flows and through the increased use of green energy. In this perspective, part of the energy needed for the Smart City will be self-produced by various city energy communities, associations that unite consumers and producers of clean energy on a local basis and that, through generation systems based on renewable sources, can contribute to electricity needs by distributing the benefits of self-production. However, it is necessary for monitoring systems of the energy produced and fed into the grid to provide instantaneous and certifiable readings.

Today, traditional systems, based on sectorial logic and not designed to provide effective answers to this need, are left to deal with this issue. On the contrary, 5G, with its speed and immediate response times due to its low latency and its pervasiveness as a solution applied to the world of Smart Cities, is an enabling factor for energy communities, which - in combination with cloud and IoT - can facilitate the creation of physical and virtual networks to support the production, distribution, dispatching, and intermediation of electricity. Big data analytics algorithms can also provide instantaneous analysis of communication and energy flows to support the individual community manager and provide the tools to assess, for example, self-consumed and surplus quantities, make strategic energy-saving decisions, and encourage a reduction in CO2 emissions.

These examples show that public decision-makers, both local and national, are called upon to make choices that favor transversality and the overcoming of regulatory barriers, even triggering real radical changes, in order to stimulate a faster take-off of Smart Cities.

Technology and data: a directorate to integrate a complex and disaggregated landscape

Innovative solutions for 'smart cities' require the availability of different types of information from a variety of sources. This means that millions of sensors will be able to upload data from streets, buildings, fixed or mobile IoT devices to a cloud system so that it can be analyzed to optimize city management.

This generates a 'digital image' of the city's ecosystem, often referred to as the 'digital twin' or digital twin, as extensively described in the chapter on Urban Intelligence.

This digital model can be used to monitor and control processes at an early stage: the efficiency of transport and energy systems, infrastructure safety and more. Digital twins can be used to obtain an overall view of the city and improve planning and service design decisions. They can be used to monitor the proper functioning of devices and provide information on how and where to invest for maximum efficiency and cost savings. However, this evolution requires a 'technology director' who must be able to combine the different pieces of the jigsaw puzzle and must be able to understand the logic of a multiplicity of actors: IoT companies, cloud service providers, telecommunication operators, companies with Artificial Intelligence solutions able to extract value from the large amount of data collected, cybersecurity actors, innovative start-ups. In the past, many cities assigned the task of managing all these aspects to local utilities, without these having the right cross-sectoral skills to perform this task.

It is also necessary to ensure that information is processed in compliance with the privacy rules of individuals, avoiding that data can be used by actors who are not fully aligned with the obligations imposed by the relevant European regulations.

There are initiatives that have emerged in recent years, such as the Gaia-X project, which are able to reconcile the collection and management of data and information in a way that is in line with European values.

Another initiative that has just been announced by some of Europe's largest telecommunications operators is the TrustPID project, which allows users to be identified without the use of cookies or sensitive information, thus avoiding the indiscriminate collection of data by the international platforms that now dominate the supply of Internet services.

A third point of attention relates to the contribution of smart cities to reducing the carbon footprint, which is an important line of study in the context of European policies to achieve climate neutrality. The European Green Deal launched by the Von der Leyen Commission in 2019 attributes a central role to digital technologies, capable of supporting the ecological transition through - just to mention a few examples - optimizing traffic flows, reducing energy consumption in buildings, and activating circular processes.

This is also made possible by the progressive replacement of traditional communication infrastructures with new networks based on fiber and 5G, and by the spread of solutions defined as 'data driven' or 'data center' by the Commission (sensors, IoT solutions, Artificial Intelligence, Cloud systems). While these technologies allow for greater control over processes and sectors, they also lead to a proliferation of digital devices and tools and a change in usage styles that increase the amount of energy used.

Financial resources and public procurement: balancing efficiency and transparency

The European funds of the National Recovery and Resilience Plan (PNRR) represent a great opportunity to transform Italy digitally and ecologically, and Smart Cities are an important and significant investment area. They are complemented by the funding made available by Horizon Europe for the 100 cities chosen to set the direction for the others and trial smart city models to be applied to other contexts.

Nine Italian cities have also been selected among the 100 European cities: Bergamo, Bologna, Florence, Milan, Padua, Parma, Prato, Rome and Turin. These cities will not only benefit from the funds provided by the program, but also from additional resources by taking part in other related initiatives, as well as from specialized consultancy services to identify projects and strategies for reducing emissions and minimizing the carbon footprint.

The resources are therefore not lacking. The main critical issue is to be able to realize the initiatives. This requires management and organizational changes, prioritizing the achievement of objectives through a rethinking of traditional processes as well.

Unfortunately, intelligent urban planning according to an integrated and holistic approach is still very limited. Indeed, most projects are still conceived and implemented on a sectoral basis.

The separation of urban management into different departments hinders cooperation and coordination among them. This could be solved by assigning Smart City competencies to a single department, which would develop integrated projects by coordinating the other areas involved (e.g. mobility, education, urban planning and security, etc.).

A fragmented approach can also be traced back to sector-specific funding schemes and opportunities, as public funds (including EU funds) are generally granted at the sectoral level. Moreover, not all types of funds are managed by the same institution (some funds are granted at EU level, others at national or local level and still others may be granted by private entities), so putting the different pieces together may prove complicated and not always feasible. Greater fluidity can lead to a redesign of public procurement, which can be planned and designed differently than in the past, so that synergies can be achieved between different classes of services and/or interventions that focus on the same areas and/or objects of urban design. In London, for example, the opportunity that arose from the repair of streetlamps was used to turn them into charging stations for electric cars.

In Italy, too, the issue of a rethink of the public procurement code, which currently tends to favor transparency and control over the speed of execution of works, is being raised from several quarters. Clearly this focus seeks to avoid the spread of corrupt phenomena and illegal practices, but at the same time it contributes significantly to increasing the time it takes to complete works. The time required to complete works worth over 100 million euro exceeds 15 years, a time that is incompatible with the speed imposed by technological development and - moreover - with the timeframe imposed by the NRP.

In addition, as also highlighted by the latest ANCE observatory, a slowdown in capital expenditure by municipalities is being observed in Italy in the third quarter of 2022 (-1% compared to the previous year), not only due to critical issues related to the increase in the price of materials, but also due to the poor administrative capacity of the entities that find themselves managing a considerable amount of resources and complex projects in a very tight timeframe.

Smart Cities represent a complex challenge to manage and require innovative solutions that balance speed and efficiency with the need for supervision and consistency with public interest objectives. This synthesis can be achieved particularly through a specialization of tasks within the same public-private partnership, where the public sector can take charge of the initial 'design' phase, leaving the private sector to lead the operational and implementation phases, while guaranteeing a strong monitoring and evaluation role.

CHAPTER 7

The Urban Intelligence perspective

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Smart City and Intelligent City

This study has highlighted several salient features of the development trends of the Smart City in Italy, among which the following aspects are useful to outline an evolutionary perspective of current trends:

- it is a development mainly promoted (and driven) by the public administrations of Italian cities of all sizes;
- it is a development often characterized by 'silo' approaches, both in relation to the types of projects developed, which are not always inspired by functional integration, and also in relation to the strategic axes that are pursued;
- The idea that the Smart City can provide valuable support for urban governance activities is beginning to gain ground, thanks to its ability to increase the value of good-quality data.

The Urban Intelligence (UI) perspective explored in this chapter aims to address these aspects explicitly. According to Komninos (2020) [192], the Intelligent City is a dimension of urban smartness geared towards enhancing skills and capacities with a view to improving its decision-making and governance processes; it is an approach that sees digital solutions as an enabling factor to foster a multi-actor, multi-level and multi-disciplinary dialogue and

[192] *Komninos N. Panori A., Kakderi C., 2021, 'The Smart City Ontology 2.0: Assessing the components and interdependencies of city smartness', Preprints, doi:10.20944/preprints202108.0101.v1*

confrontation that is indispensable to address the urgent challenges that beset cities in the contemporary world.

The strategic project "Urban Intelligence" (UI) of the CNR[193] aims to develop an ecosystem of integrated digital technologies that can effectively support urban governance in achieving the sustainability objectives defined by international policy documents such as the UN 2030 Agenda, the UN-Habitat Urban Agenda and the European Urban Agenda.

The project proposes to overcome the silo approach still widespread in Italian cities by integrating the social, economic, environmental, and spatial domains of sustainability.

This requires adopting a multi-level urban innovation path with the goal of:

- developing integrated approaches and policies for urban sustainability;
- enhancing the knowledge framework on the city, especially of a multi-disciplinary nature;
- coordinating technological innovations with governance innovations;
- strengthen civic inclusion and participation in a structural manner.

The UI strategic project responds to these demands not only with a program for the development of innovative technologies at the service of cities. First and foremost, it proposes a strategy to accompany Italian cities in equipping themselves with the digital skills and capabilities needed to face the challenges of sustainability.

To this end, UI looks at the city as a complex, dynamic, and evolving system (Batty, 2008)[194] whose whole is much more than the sum of its parts, and whose overall behavior does not immediately follow from the laws that describe the behavior of its individual components; with the result that a complex system is difficult to predict through deterministic approaches, since by its very nature it generates unpredictable results, which often remain hidden from local or sectoral observations (Parisi, 2021) [195].

This is how complex systems differ from simple or complicated ones, which are characterized by a large number of components (as in the case of clock mechanisms), but which interact with each other in a predictable manner.

Perrow (1984)[196] identified two main reasons for the human difficulty in interacting with complex systems. There are technical reasons, linked, for example, to the difficulty of managing and processing large quantities of information: this is a difficulty that recent

[193] *Project coordinated by the Department of Engineering, ICT and Technologies for Energy and Transport (DIITET) of the National Research Council (CNR)*
[194] *Batty M., 2008, 'Cities as Complex Systems: Scaling, Interactions, Networks, Dynamics and Urban Morphologies', UCL Working Papers Series, paper no. 131*
[195] *Parisi G., 2021, "In un volo di storni. Le meraviglie dei sistemi complessi", Rizzoli publisher*
[196] *Perrow C., 1984, Normal accidents: Living with high-risk technologies, New York: Basic Books*

advances, including those of the Smart City, have partly overcome (think of IoT and Big Data, Data Science, or High Performance Computing).

The second reason is the human difficulty of 'making sense' of complex phenomena which, by presenting apparently heterogeneous and contradictory information frameworks, make it difficult to extrapolate unambiguous interpretations; as if humans struggle to find an orientation in complexity, and by struggling to find their bearings, also their ability to understand, and thus, to make good decisions is affected.

This is the direction in which Nobel Prize winner Giorgio Parisi's studies move, oriented towards investigating complex phenomena in terms of a multi-scale investigation through which to trace the hidden connections between local and global behavior in a system.

The importance of sense-making is a field in which technologies can certainly provide valuable help, but which they alone struggle to satisfy (for example, the enormous amount of data generated by a Smart City can be a problematic element in itself, if this data is not already geared from the outset to satisfy a need for knowledge that pursues a clear urban policy objective).

And this is precisely where the idea of Urban Intelligence comes into play.

Assuming the point of view of complex systems implies, first of all, resetting the traditional modes of knowledge, overcoming the collection of specialized knowledge in favor of a deeper understanding of the ways in which the individual levels and components of the city connect and influence each other, especially in the light of the objectives urged by the challenge of sustainability.

This translates into the need to better focus on the correlations between the various urban phenomena, highlighting those emerging behaviors[197], unpredictable and even unthinkable, that arise as a natural consequence of the reactions that cities develop in response to the more or less planned stresses to which they are subjected.

Secondly, it means exploring the nature of complex behaviors in light of the meanings they have for the city's main actors, namely its inhabitants and citizens. It reveals the deep motivational substrate, including the emotional one, that forms the main matrix, the horizon of meaning in which the actions of the various social groups and relational networks that constitute the body of a local community are rooted. These actions range from the simple enjoyment of the spaces, services and opportunities that the city offers to the interplay of the sometimes conflicting interests that are woven into the webs through which a city evolves and transforms.

[197] *Grieves M., Vickers J., 2017, 'Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems', in Kahlen F. J., Flumerfelt S., Alves A. (eds.), Transdisciplinary Perspectives on Complex Systems: new findings and approaches, Springer*

The ecosystem of digital tools proposed by UI for this purpose differs from the state-of-the-art Smart City solutions landscape in the following distinctive points[198]:

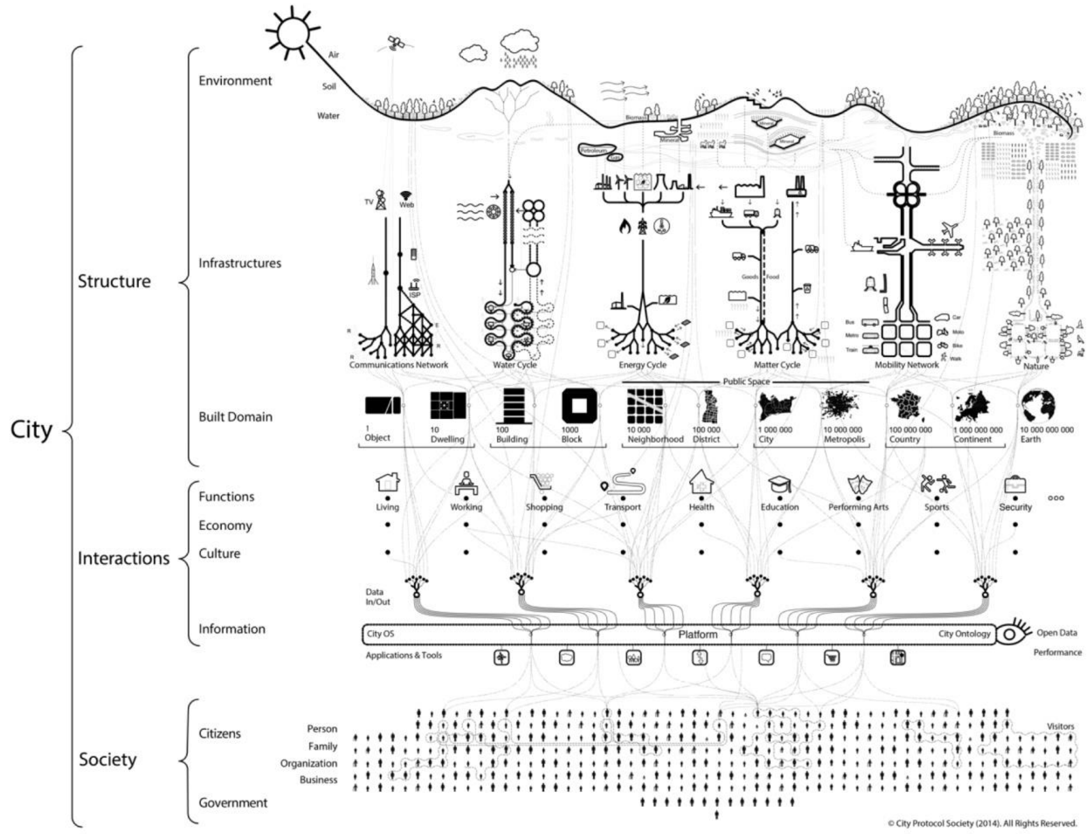
- is fully functional to the needs of a city government oriented towards greater sustainability of its processes and dynamics;
- enables complex and interdependent analyses of the thematic layers and (sub)systems of a city, including through the adoption of Artificial Intelligence techniques;
- is natively built to interface with 5G and IoT technologies, and to support highly complex and dynamic scenarios;
- is open to the human and social dimension of cities, integrating within it participatory practices of civic involvement and multi-actor dialogue with stakeholders, including through the adoption of dedicated digital tools;
- is modular, in that it can be applied alternatively to limited portions of an urban system, to a limited number of thematic layers/(sub)systems, to a limited number of interactions between layers/(sub)systems, favoring the economic and managerial sustainability of an initial implementation of the UI, and leaving open the possibility of subsequent extensions linked to the priorities of the local urban and digital agenda.

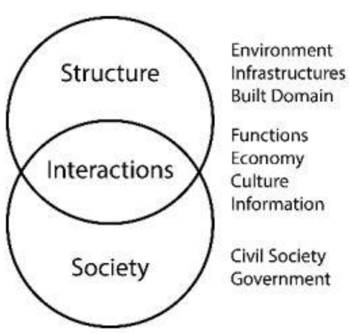
Thanks to these characteristics, UI promotes the evolution of current urban governance schemes towards greater transparency, objectivity, integration, adaptability, and sharing of policy- and decision-making processes in a multi-sector and multi-level perspective. This requires taking an integrated view of the city from the outset, on the one hand defining its syntax at the level of a complex system, and on the other highlighting the specific role that each component plays within it. International experiences such as that of the City Protocol (2015) [199], led by the city of Barcelona, may provide a useful reference in this direction.

[198] *Castelli G. et al., 2022, 'Urban Intelligence: towards the Digital Twin of Matera and Catania', 2022 Workshop on Blockchain for Renewables Integration (BLORIN), Palermo, Italy, pp. 132-137 doi: 10.1109/BLORIN54731.2022.10028437*
[199] *City Protocol, 2015, CPA-I_001-v2_City Anatomy*

City Protocol views the city as an ecosystem that consists of two main components: the urban structure (the habitat) and the society (the city dwellers). For each of these components, the Protocol identifies, analyses and describes the most relevant elements, highlighting their main dynamics and differences, and examining their subcomponents. The Protocol also considers the interactions between the urban structure and the society, and how they affect the city's performance in environmental sustainability, economic competitiveness, quality of life, and city services.

Outline of the City anatomy according to the City Protocol [200]

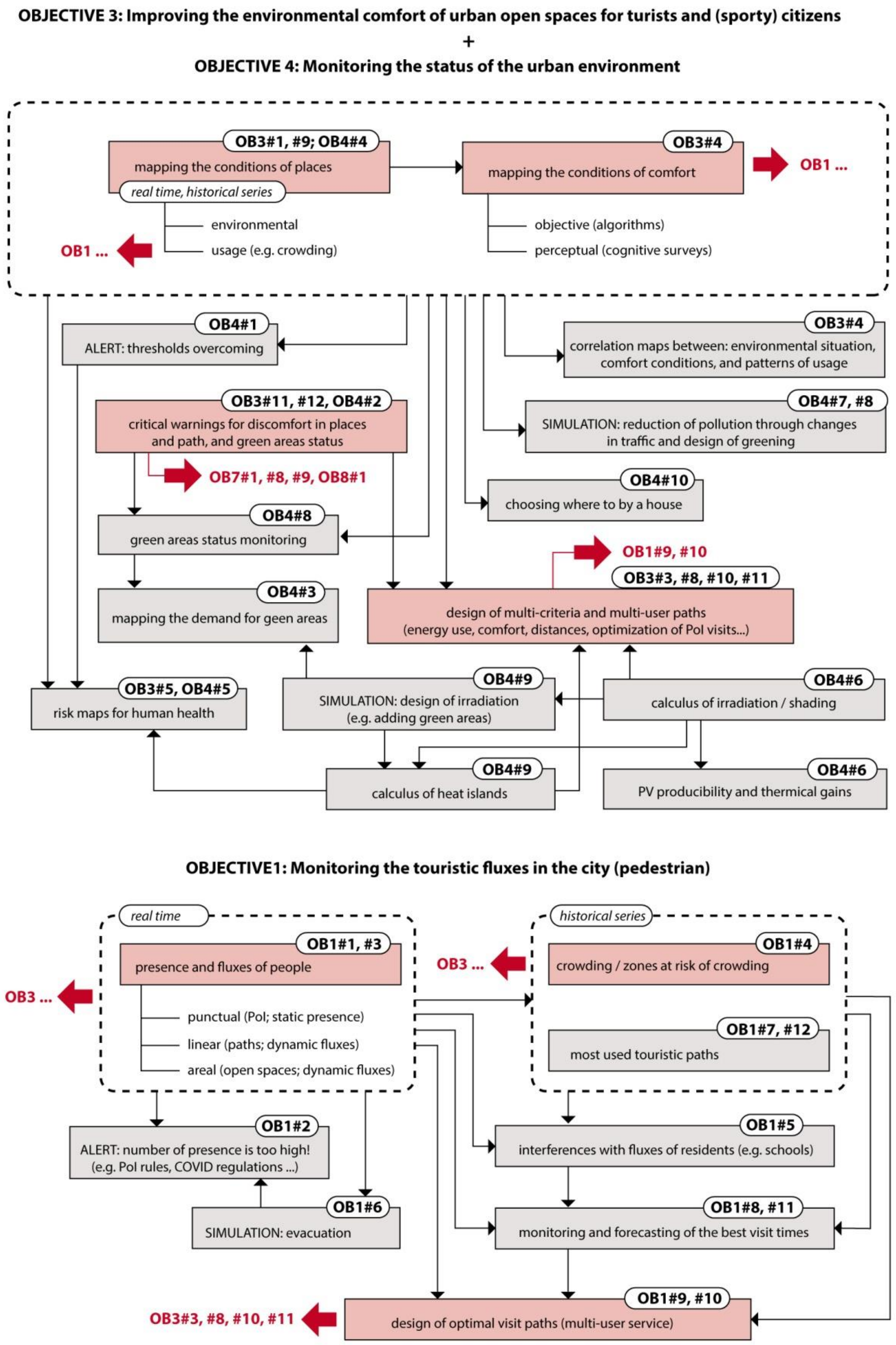




The integrated UI approach is also reflected in how the digital solutions available to the city interact. Starting from knowledge systems, based on historical time series or real-time data, so-called 'atomic' services are defined. These provide answers to specific thematic problems at a first level, characteristic of the traditional Smart City approach.

[200] *Source: City Protocol, 2015, "CPA-I_001-v2_City Anatomy"; copyright: © City Protocol Society (2015-2016), all rights reserved, https://cityprotocol.cat/politica-de-privadesa/*

Example of multi-objective logic-conceptual scheme for Urban Intelligence[201]



At a higher level, these atomic services deliver information processing that progressively contributes to feeding more complex services, developing an articulated relational

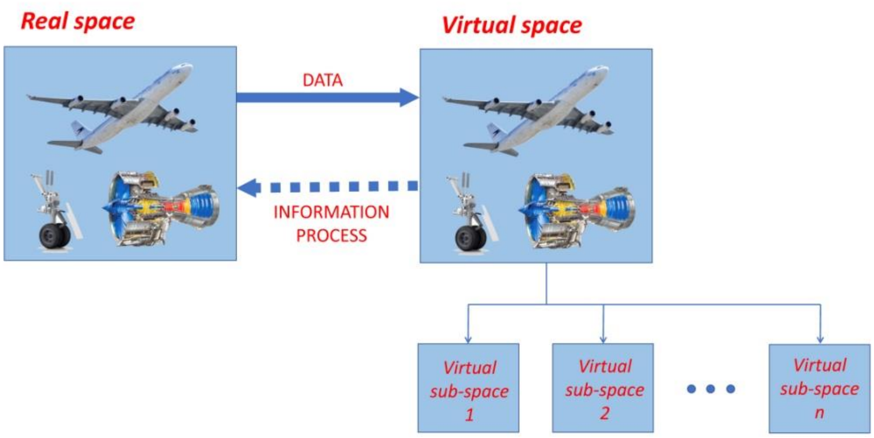
[201] *Source: R. Malvezzi et al., 2022, Report no. 1.5.3 of the "Casa delle Tecnologie Emergenti di Matera" project*

architecture that enables the construction of answers to multidisciplinary problems capable of acting transversally between different thematic objectives. The diagram on the previous page illustrates an example of UI architecture relating to thematic objectives such as the management of pedestrian tourist flows, comfort in public spaces and the quality of the urban environment, where the individual elements are the individual services, the flow lines define the networks of relations (input-output) between them, while the red arrows indicate the interdisciplinary connections between services (marked in pink) that allow us to look at this architecture as a three-dimensional system capable of supporting the simulation of integrated and complex scenarios.

The Digital Twins for Urban Intelligence

The main tool with which UI intends to make its ecosystem of digital solutions available to cities is the 'Urban Digital Twin' (UDT). That of the Digital Twin (DT), in a general sense, is a concept introduced in 2002 under the name 'Information Mirroring Model' (Grieves, 2016)[202] , meaning a virtual copy of a real process capable of automatically updating itself to reflect, at any given moment, the current state of the real phenomenon.

Conceptual diagram of the Information Mirroring Model [203]



In this sense, a Digital Twin is said to be 'coupled' to the phenomenon it reproduces, through a continuous flow of data and information from advanced sensor networks, which allow it to update in real time as the twinned phenomenon changes. This is why we also refer to DTs as 'cyber-physical systems' composed of three elements: the real phenomenon, its virtual copy, and the network of connections between the two.

[202] *Grieves M., 2016, 'Origins of the Digital Twin Concept', working paper*
[203] *Source: elaboration from Grieves, 2016*

This is also the basic difference between a Digital Twin and a virtual representation, or a 3D model: the latter merely represents the state of a phenomenon at a given time – the time when the model is made.

The potential inherent in the Digital Twin technology is closely linked to the development of digital technologies such as 5G and IoT networks, Artificial Intelligence, Data Science, and High Performance Computing (HPC); thanks to these, in fact, DTs are able to acquire a large amount of information on the real phenomenon over time, and on this basis, to carry out in-depth analyses on how it evolves and changes over time, also in the light of exogenous stimuli, and thus, to make more precise estimates on how it will continue to evolve in the future.

Moreover, they make it possible to simulate a large number of operations on the real phenomenon with reference to each point in its history, and thus, to test and program certain actions even in asynchronous mode, without having to intervene on the phenomenon itself. In this sense, a DT is not just a simulation tool: it aspires to be an 'intelligent extension' of a real phenomenon in the virtual space, through which the natural evolution of that phenomenon is in fact modified, thanks to the continuous flow of feedback information derived from the processing activities of the data entering the DT, which generate a continuous learning and optimization loop.

For these reasons, DTs initially found wide application in industry; in more recent years, this technology has also found increasing application in cities, leading to the development of the specific concept of Urban Digital Twins (UDTs).

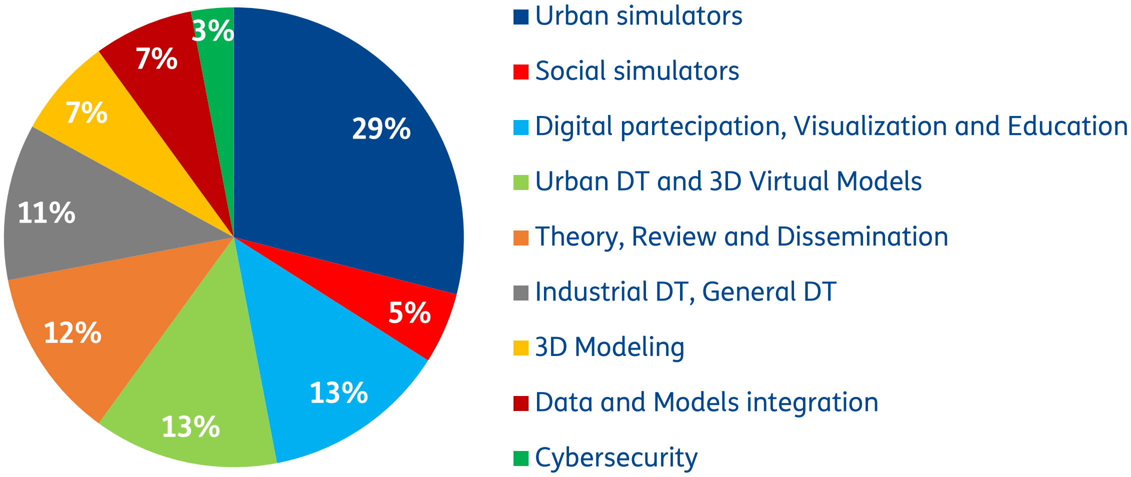
According to Elliott T. (2019), there are numerous benefits that cities can gain in this way[204]:

- acquire new knowledge about urban processes, dynamics and infrastructure;
- strengthen collaboration across a broad ecosystem of stakeholders, generating new value for all inhabitants;
- improve mobility and safety in urban spaces;
- improve urban planning and visualization of projects;
- strengthen urban resilience through improved prediction, response and recovery capabilities;
- involve the local community in an interactive way;
- adopt open data initiatives, fostering the exchange and use of quality information.

[204] *Teresa Elliott, 2019, '7 Ways Cities Benefit from Digital Twins'*

Indeed, the bibliography on UDTs at an international level is constantly growing. An analysis of the scientific literature cited in the *survey paper* by (Ketzler et al., 2020)[205], which reviews some 140 publications on the subject, highlighted the panorama on the topics of greatest interest.

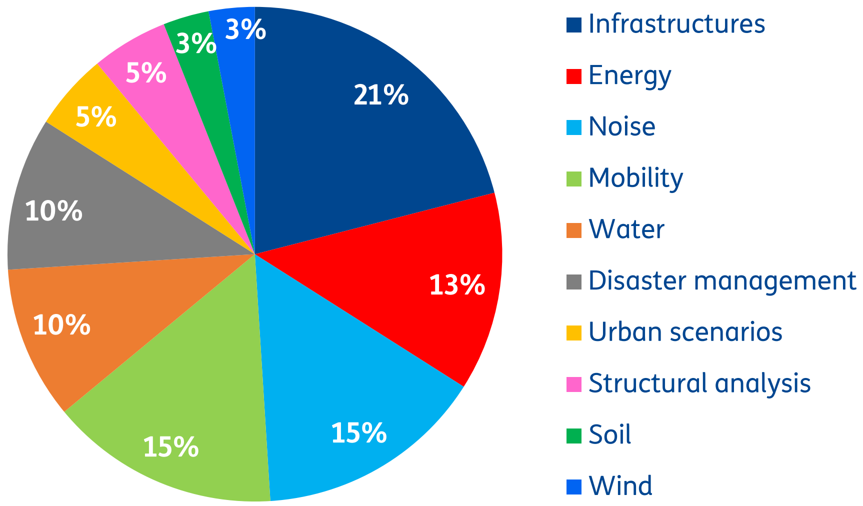
Themes from the literature[206]



Simulation of urban systems, processes, and dynamics constitutes the most cited field of research, followed by topics related to digital participation, visualization, and 3D modelling at the urban scale. Narrowing the field to the specific case of simulators, the scenario shown in the graph below shows that the most frequently explored topics are related to infrastructure, energy, noise, mobility, water, and disaster management.

[205] *Ketzler B., Naserentin V., Latino F., Zangelidis C., Thuvander L., Logg A., 2020, 'Digital Twins for Cities: A State of the Art Review', Built Environment 46(4):547-573*
[206] *Source: analysis and elaboration by R. Malvezzi (DIITET-CNR, 2021) based on Ketzler et al., 2020*

Types of Urban simulator[207]



This study is not exhaustive of the existing bibliography, but it illustrates sufficiently the main research trends underway. Research on data and model integration, as well as on simulators and urban-scale scenarios, appears rather marginal.

The table below presents the results of a comparative survey on some relevant UDT case studies at an international level (Caprari et al., 2022)[208], which report their main characteristics in terms of scale, objectives, technologies, experimentation, strengths and weaknesses. The study highlighted that there is still a gap between the expert use of these tools and their actual ability to trigger representative processes of involvement of local communities in cognitive, projective and decision-making processes related to urban transformations.

At the same time, it highlighted a poor connection between the tools and information made available to cities on the one hand, and the level of urban strategies on the other, which instead need qualitative-quantitative explorations of the different contexts, introspection into the needs and feelings of local communities, and an awareness of their structural weaknesses. Finally, it highlighted an emerging role of technologies such as artificial intelligence in the development of complex analyses.

[207] *Source: analysis and elaboration by R. Malvezzi (DIITET-CNR, 2021) based on Ketzler et al., 2020*

[208] *Caprari G., Castelli G., Montuori M., Camardelli M., Malvezzi R. 2022, 'Digital Twin for Urban Planning in the Green Deal Era: A State of the Art and Future Perspectives', Sustainability, 14(22):14893. DOI: https://doi.org/10.3390/su142214893*

International comparative survey of UDTs[209]

	Case studies			
	Cambridge	Zurich Dublin, Helsinki	Herrenberg	Singapore
DT Types	Static and managerial	Dynamic-evolutionary	Dynamic-evolutive and collaborative	Dynamic-evolutionary
Stairs	Supra-municipal	City, sub-areas, district	City	City-State
Purposes	Multi-level governance and platform for cooperation between planning levels	Data-driven preventive assessment, creation of simulative and predictive scenarios for sustainable urban development policies/actions	Consensus building, involvement of interested citizens, democratization of decision-making processes	Development of a high-tech decision support platform
Technologies	GIS-processing	GIS-BIM, Laser Scanner, UAV (Unmanned aerial vehicle), IoT, Open Source software	GIS-BIM, Lidar, IoT, AR/VR, Open-Source software	GIS-BIM, high-resolution satellite imagery, Lidar, Remote Sensing, Deep Learning, Machine Learning, AI
Experiments	Traditional urban planning surveys prior to the elaboration of the project; simulation of local energy demand in a 'what if' scenario of electric mobility considering future housing and work policies	Simulations of crisis and prevention scenarios (floods and run-offs, thermal stress, exposure to pollutants) aimed at developing site-specific strategies Urban microclimate analysis (ventilation, shadow study, solar radiation)	Augmented reality applications (AR/VR) in public events and workshops App development for data collection (VGI); mobility and traffic simulations for awareness-raising on anthropogenic pollution issues	Climate simulations from city-scale (City-GML) to building-scale (BIM) with different application tools integrated in DT; 3D tree census with semi-automated technological procedures; maximum accuracy of the built environment (LOD3)
Strengths	DT as an instrument of coordination between planning levels; Strategic analysis of the local governance structure; Involvement of citizen representatives	High-tech 3D model Simulations in critical climate scenarios DT models in open data	Multi-participatory activities; Advanced technological tools (AR/VR) + GeoApp data collection (VGI); Simulations from sensors data	Realistic DT (LOD 3) and advanced Technological instrumentation; Open-space characterization (3D vegetation); - Macro-micro energy/climate scenarios from measured and simulated data
Weaknesses	Undeveloped virtual 3D model Limited simulation capabilities	Morphology of open space not taken into account; General low interoperability and users' involvement (workshops, tools, feedback, and reports); Few simulations from IoT-synchronized data	Lack of proactive proposals and/or scenarios; Lack of relationship with government and territorial governance	Risk of lack of data transparency (proprietary software) - Lack of a co-design system and/or participatory processes

The UDT concept, carried out according to the Urban Intelligence paradigm, addresses the limitations highlighted by these investigations by enhancing the integration capabilities of different scenarios and layers of the Twin. It also extends the coupling process beyond infrastructures and flows to involve also the city's users and their interactions, highlighting their habits and specific preferences. These characteristics make it possible to regard UDTs for the UI as 'cyber-physical-social systems' (Notcha et al., 2020)[210], which evolve with the city and learn from it, allowing for a deeper understanding of the complexity of its dynamics even as they change. In particular, thanks to the unprecedented potential offered

[209] *Source: elaboration from Caprari et al., 2022*
[210] *Nochta T., Wan L., Schooling J. M., Parlikad A. K., 2020, 'A Socio-Technical Perspective on Urban Analytics: The Case of City-Scale Digital Twins', Journal of Urban Technology, DOI: 10.1080/10630732.2020.1798177*

by the new digital technologies in terms of analysis and prediction (artificial intelligence and machine learning), simulation (high-performance computing), optimization and decision support (multi-objective and multi-disciplinary optimization, multi-criteria analysis), UDTs enable (Castelli et al., 2020)[211]:

- develop integrated and intelligent management systems that use data and information collected from different sources (both time series and real-time) to offer real-time data aggregation and analysis capabilities;
- develop a holistic, flexible and adaptive digital model of the city that allows the simulation, assessment and governance of the necessary transformations of different systems and subsystems according to safety and quality of life requirements;
- build a predictive model that can anticipate system behavior and the most likely scenarios towards which the system evolves by constantly monitoring the evolution of the state of the systems.

In particular, UDTs make it possible to strengthen urban governance on two-time scales:

- the operational scale, whether instantaneous or short-term, enhancing its ability to react more promptly and effectively to new critical situations and emergencies;
- the medium- to long-term strategic scale, enhancing its capacity to generate more forward-looking and stable sustainability policies.

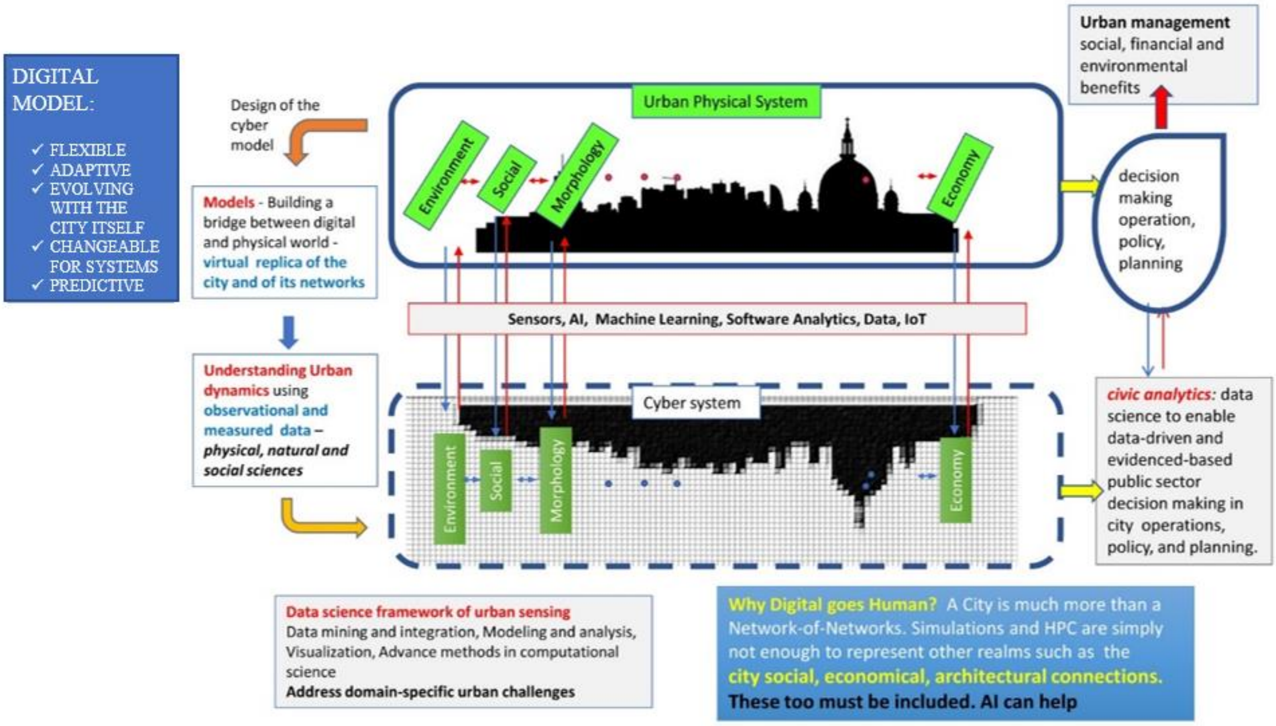
The following figure details the conceptual model of the UDT summarized above. To achieve these results, the UDT is organized into three main levels (Castelli et al., 2022):

- *the data layer, consisting of the city's different knowledge sources, such as sensor networks, connected databases, and the data lake that handles data storage, pre-processing and distribution;*
- *the analysis level, where modelling, including 3D modelling, simulation and data processing of the different (sub)systems of the city takes place;*
- *the decision-making level, which supports both operational and strategic level decisions through the use of mathematical, logical or simulative models of the different systems involved and their multidisciplinary combination.*

Completing the UDT system is a multi-user dashboard that allows the display of information or the use of services tailored to each end-user profile. The overall architecture of the UDT is thus depicted in the following image.

[211] *Castelli G, Spagnuolo M., Tognola G., Ravazzani P., Rinaldi G.,Cesta A., Diez M., Padula M., De Pietro G., 2020, LV-UI: il Gemello Digitale per lo sviluppo sostenibile ed intelligente della città, DIITET-CNR Technical Report*

The UDT conceptual model of Urban Intelligence [212]



The UDT for the UI is thus configured as a 'system of systems', in which the modelling of the different urban (sub)systems takes place in the form of Thematic Digital Twins (TDTs), each characterized by dedicated simulators, data, models and services, concerning the most important topics for the local urban agenda, such as mobility, environmental and air quality, energy consumption, cultural heritage, etc. The TDTs are integrated at the higher-order level, which assumes the function of an access door for both simple queries addressed to the individual Thematic Twins and complex queries made through the higher-order modules. In particular, this level includes the following modules:

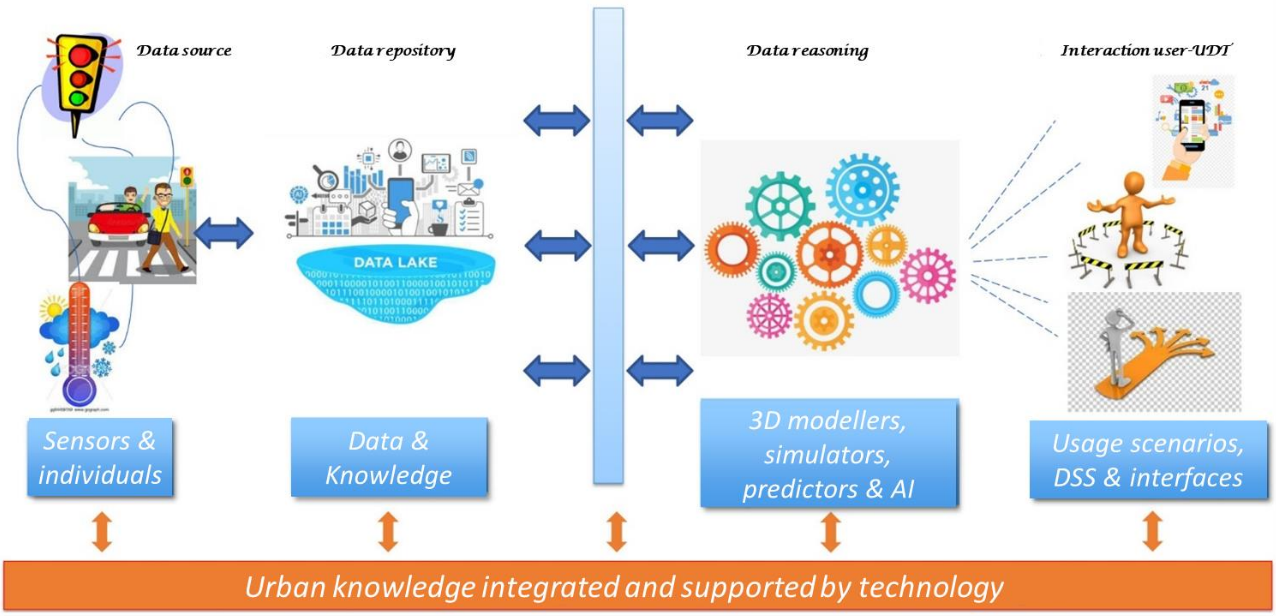
- Urban Sensing Engine (USE), which includes an expert system for thinking in terms of 'if-then' rules, and a deliberative tool to support action planning (e.g. related to maintenance);
- Correlation analysis between data produced at different thematic levels, aimed at knowledge extraction and prediction, and based on AI and statistical machine learning techniques;
- Component capable of generating complex scenarios and evaluating them implicitly via multi-objective, multi-disciplinary optimization (MDO) algorithms;

[212] *Source: Castelli et al, 2020*

- A Decision Support System (DSS) based on the comparative evaluation of complex scenarios generated automatically or submitted by the user, using multi-criteria optimization and analysis (MCA) methods.

The following figure illustrates the overall architecture of the UDT, highlighting the different levels of which it is composed.

UDT Architecture for Urban Intelligence[213]



This architecture enables both the modelling of urban (sub)systems independently of one another and the creation of an integrated knowledge base that can support the implementation of data-driven and evidence-based policies aimed at achieving the goals of the UN 2030 Agenda.

This work of integrating the Smart City is pursued in the UDT in three directions: at the level of data, thanks to a Data Lake that can manage, pre-process, and distribute any type of data to higher-level services; at the level of analysis, thanks to an ICT platform that can connect and enable communication between models and services related to different thematic areas; at the level of decision-making, thanks to the possibility of drawing on all these resources to build models of the subsystems and, through these models, generate and compare complex scenarios.

[213] *Source: CNR-IMATI, 2022*

The architecture of the UDT thus stands in continuity with the Smart City scheme described in this study, compared with which it introduces two further (sub)layers. The first is the geometric layer, which is called upon to represent the morphology of the built environment. Depending on the purpose of use, this morphology can be modelled in different ways:

- through 'point clouds', i.e. a large number of geo-localized points typically obtained by sampling with LiDAR or photogrammetric surveying techniques;
- using 'surface meshes', i.e. made up of points and polygons, which can be used for better graphical rendering and for solving problems involving the surface of objects (such as for the calculation of shading); the points generated in this case are typically fewer in number than in point clouds, so as to reduce the computational burden;
- by means of 'volumetric meshes', i.e. composed of points and polyhedral, which can be used for simulations based on physical models; the resolution in this case is typically much lower than in the two previous cases.

The geometric layer of the UDT constitutes not only a 3D representation of the built environment, but above all a valuable source of information that can also be obtained in various ways:

- geometric measurement or photographic analysis of urban contexts;
- semantic annotation of the built environment, thanks to which it is possible to identify portions of geometry (buildings, streets, furniture, etc.) with which to associate localized information on the model;
- dynamic simulations in a 3D environment (e.g. diffusion of pollutants or solar radiation).

The adoption of the CityGML[214] standard for 3D modelling (in particular the new version 3.0), thanks to the possibility of defining different Levels of Detail (LoD) of the built environment, allows the UDT's digital services to provide the optimal urban geometry for different uses, where LoD0 represents the semantically enriched DTM (Digital Terrain Model), up to complete and detailed 3D representations of buildings (LoD3).

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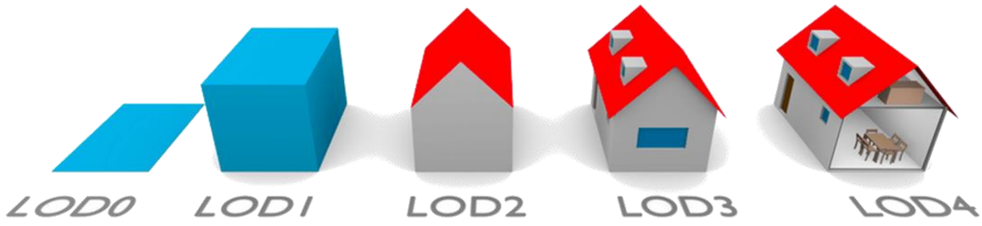
[214] *City Geography Markup Language, developed by the Open Geospatial Consortium (OGC)*
Link: https://www.ogc.org/standard/citygml/

Levels of Details (LoD) according to the CityGML 3.0 standard[215]



The second additional level is the higher-order one, in which the progressive and modular integration of the different thematic digital twins coupled with the individual sub-systems of the city takes place. This feature is the main innovation factor of the UI approach; it is based on the ability to develop and employ methods of analysis, modelling and resolution based on frontier expertise in different scientific disciplines, and to equip oneself with the computational tools necessary to make the models of the different subsystems part of an organic whole. This can only be achieved through the correct combination of a large amount of data, the computational intelligence required to extract useful information from it – circumventing the phenomenon of data deluge – and the development of multidisciplinary models and algorithms capable of integrating the different faces of a city governance problem with the necessary precision.

This comparison enables us to frame the perspective of Urban Intelligence outlined in this chapter as a potential evolution of the very idea of the Smart City. It offers Italian cities the opportunity to equip themselves over time with innovative digital tools that are calibrated and proportionate to their progressive adoption. This is based on a careful assessment of the benefits obtained over time and of the paths of innovation and adaptation of the public administration necessary for this purpose. The strategic value of the UI project lies precisely in this: in its ability to propose a path of innovation that allows for the implementation over time of a flexible digital agenda. It starts from an initial core of experimentation in the Smart City field and gradually adds on new solutions, themes, and levels until evolving into real UDTs of increasing complexity[216].

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[215] *Source: Open Geospatial Consortium, 2021, "OGC City Geography Markup Language (CityGML) 3.0 Conceptual Model Users Guide", link: https://docs.ogc.org/guides/20-066.html#overview-section-levelsofdetail; copyright: © 2021.09.13, Open Geospatial Consortium, Inc. All Rights Reserved. http://www.ogc.org/ogc/document*

[216] *This strategic framework for an adaptive and modular innovation of the governance capabilities of Italian cities was presented by DIITET-CNR at UrbanPromo Digital 2021, with the event: "Digital Technologies as Enabling Factors for Urban Governance" (co-organized by CNR), which saw the experiences on Urban Intelligence compared with those of other Italian cities in the field of Intelligent SITs, Smart Control Rooms and Urban Digital Centers (link to program: https://urbanpromo.it/2021/eventi/tecnologie-digitali-come-fattori-abilitanti-per-la-governance-urbana/)*

The Digital Twin model, indeed, thanks to its intrinsic assumptions of scalability, interoperability, adaptability and modularity, constitutes a platform that can be expanded on four levels of scale: *territorial* (by twinning only one portion of the city and then adding others), *complexity* (starting with a limited number of layers, to be expanded later as needed), *integration* (by gradually increasing the number of interactions between the sub-systems considered by the Twin), and *sensitivity* (using sensor networks with varying density and type). These four scales, or dimensions, can be extended by starting with an initial platform that is relatively simple to design and implement, and then by evolving it into more articulated forms, enriching the Twin with complexity, depth and utility. This will make it possible to apply the UI model to the Italian cities, by operating at first in parallel with traditional management methods and learning from them, by complementing and integrating the Smart City projects that may already exist, and then by progressively exploring the new capabilities implicit in the use and implementation of such a powerful tool.

The UI project is not limited to the urban scale, which is its initial scope: the horizon of sustainability, as outlined by the 2030 Agenda, indeed encompasses a higher order of scale, looking at 'a world in which humanity lives in harmony with nature'. The sustainability of our cities cannot be achieved by remaining within the perimeters of urbanized areas: it also involves the management of the territories in which cities are embedded. It is from these territories that cities derive their sustenance, in terms of nutrients, resources and energy that feed their metabolic fluxes; it is in these territories, with their biodiversity and capacity to provide ecosystem services, that a solution to the problems of urban resilience must be sought upstream; and it is in these territories, with their natural environments and cultural landscapes, that an essential component for human well-being must be identified.

To this end, on 14 March 2022, DIITET-CNR[217] organized, together with the Departments DSSTTA[218] and DiSBA[219], and in collaboration with MAECI[220], the event 'Land-City-Sea-scape Intelligence'[221], which took place in the setting of the Italian Pavilion at Expo Dubai, and which saw researchers from the three Departments discussing together with guests from the Arab Emirates and young CNR researchers on multidisciplinary and systemic perspectives for a rational and sustainable use of the planet's resources. The event served to explore a new idea of 'intelligence' in the fields of the Earth, the City and the Sea, based on the use of innovative technologies (including that of the Digital Twins), and aimed at fostering an integration between these fields of research in terms of generating and analyzing data and information, simulating predictive scenarios, and supporting decision

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[217] DIITET: CNR Department of Engineering, ICT and Technologies for Energy and Transport
[218] DSSTTA: CNR Department of Earth System Sciences and Technologies for the Environment
[219] DiSBA: CNR Department of Bio-Food Sciences
[220] Ministry of Foreign Affairs and International Cooperation
[221] Link to the event program: https://www.isafom.cnr.it/images/COMUNICAZIONE/Locandine/EXPO.pdf
Link to video recording of the event: https://www.youtube.com/watch?v=gcaWuefQuxg

making. The results obtained made it possible to focus on a broad set of common reflections, perspectives and objectives, which led to the identification of the following shared research and development directions, interconnected by what has been defined as 'the challenge of complexity'; these holistic research directions constitute the future development horizon for the Urban Intelligence strategic project[222].

Better knowledge

is about developing new approaches and solutions to increase knowledge. To this end, it is necessary to understand exactly what one needs to know and why; to place information precisely in space and update it at an appropriate pace; to enhance the predictive capacity on the evolution of phenomena; and to adopt systemic approaches capable of analyzing their interconnections in an integrated manner, overcoming sectoral or partial approaches.

Better tools

refers to the development of appropriate technological tools to meet the challenge of complexity. To this end, it is necessary to define well-defined innovation trajectories that start from an accurate assessment of real needs, a careful evaluation of priorities, and the clear identification of objectives to be pursued.

Better societies

this theme explores the role of people and communities within the Land-City-Sea system. It aims to better understand people's real needs, languages, and behaviors, so that solutions can be developed that are comprehensible, acceptable, and effective for local communities. It also seeks to transform digital platforms into genuine 'social infrastructures' that can influence established behaviors and habits, thereby promoting the advancement of local communities.

[222] *The Dubai event found a further moment of development at UrbanPromo Digital 2022, with the event co-organized by the CNR: 'The Shapes of the Future: Digital Technologies in Support of Territorial Resilience'. During the day, researchers from the three CNR Departments present in Dubai participated in discussion panels, each consisting of representatives from the worlds of research, administration, business and finance, and dedicated to the themes of climate change, agriculture, mobility and innovative governance. These panels were an opportunity to deepen the reflections initiated in Dubai on the themes of the Sea, the Earth, the City, and a cross-sectoral Digital Intelligence, respectively. Here are the links to the program of the event's sessions:*
https://urbanpromo.it/2022/eventi/le-forme-del-futuro-tecnologie-digitali-pima-sess/
https://urbanpromo.it/2022/eventi/le-forme-del-futuro-tecnologie-digitali-seconda-sess/

Strengthening civic participation and multi-actor dialogue

In the preceding paragraphs, the idea has taken shape that the Urban Intelligence paradigm is not only a technological innovation project, but aspires to be the promoter, thanks to the development of digital technologies, of a true **urban innovation process** aimed at pursuing sustainability objectives in an integrated manner. To this end, UI deploys a wraparound approach, which involves, on the one hand, the construction of an advanced technological tool (the UDT), and on the other, the implementation of a path of social interaction aimed at maturing a profound sharing and awareness of the results achieved at every level of the process, not so much through the search for a consensual or concerted arena, but rather through the valorization of the diversities and even the conflicts between the different souls of the local community, understood as an indispensable source of a denser and more articulated knowledge of urban dynamism.

The main objective of UI's participatory approach is to foster, within civil society, the culture of listening to the inhabitants again, considering them as the key actors for the future of cities. To this end, the UI strategic project proposes a methodology that involves the activation of 'Urban Culture and Civic Awareness Workshops' adapted through different tools and languages according to the different target groups. The starting point of the process consists in understanding the value and meaning that the places and public spaces of a city have for its own inhabitants, in order to reveal behaviors and relations that might otherwise be invisible to the expert eye. Such an investigation, inspired by the 'community mapping' approach, allows exploring the background of motivations, interpretive keys, social and cultural assumptions, experiences and projections that constitute the cognitive map of reference for a local community, and that thus exert a great influence on its way of interacting with the urban context (Malvezzi, 2021) [223].

The result of this path is twofold: on the one hand, it enables us to draw new urban geographies that constitute the ideal complement to the formal and objective knowledge of the city, as extrapolated from the knowledge systems of the Smart City; on the other hand, it aims to stimulate greater affection and care for the common environment, greater respect and sharing of social practices, and a better projection towards prospects of sustainable local development in relation to all the fundamental fields with which this term must be declined today. The participatory approach promoted by UI is based on three fundamental principles (Malvezzi, Castelli and Camardelli, 2022) [224]:

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[223] *Malvezzi R., 2021, 'For a cognitive urbanism: the listening path for the preliminary planning document of Borbona', Territory 97:113-122, DOI: 10.3280/TR2021-097015*

[224] *Malvezzi R., Castelli G., Camardelli M., 2022, The participatory program for the Matera Digital Twin, DIITET-CNR Technical Report*

- multi-dimensionality, as defined in the New Leipzig Charter, which proposes the integration of the four dimensions: historical/aesthetic/morphological, environmental, economic, social of the city, and in the 2012 UNESCO Recommendation on the Historic Urban Landscape, where an approach based on the interrelation between physical forms and spatial organization, natural and environmental characteristics, social, cultural and economic values is central;
- the multidisciplinary/interdisciplinary approach addresses the nature of the different components that constitute the concept of 'territorial heritage'. These components include historical, archaeological, architectural, environmental, landscape and socio-economic aspects. This approach requires the activation of various skills, professionalism and tools that cooperate to identify integrated actions and process strategies.
- the implementation of a cultural co-creation path that involves continuous actions and interactions throughout the process, stimulating feedback, checks, monitoring and adjustments as a guarantee of flexibility and adaptability necessary for the sustainability of policy-making.

Such a path of social interaction does not end with the extraction of data or information lying latently in the living body of the community, nor with a convergence towards design or transformative scenarios: it constitutes a true path of co-creation of experiential knowledge and horizons of meaning which, as such, do not reside only in the ex-ante input of the individual participants, but require social interaction to mature in their slow composing, and to become the recognized and shared heritage of a community.

Dynamism and the inter-relational dimension are thus placed at the basis of the participatory context: this objective can be pursued by avoiding, for example, establishing rigid procedures for managing and controlling the methods and outcomes of the process, aiming instead at encouraging open-ended participation and fostering as a prerequisite for the formation of new networks of generative and supportive relations between the inhabitants and the Administrations, giving in this way the inhabitants the possibility of reinventing themselves, and creating fertility in the discussions on the objectives that the Twin is called upon to analyze.

Such a path can in turn find in digital technologies a formidable support; in particular, UI natively includes PPGIS (Public Participation GIS) solutions that allow for large-scale geo-referenced surveys within the local community. The body of information constructed in this way already constitutes itself an information layer, of a participatory type, that can be directly integrated both in the Data Lake and in the services placed at every level of the UDT.

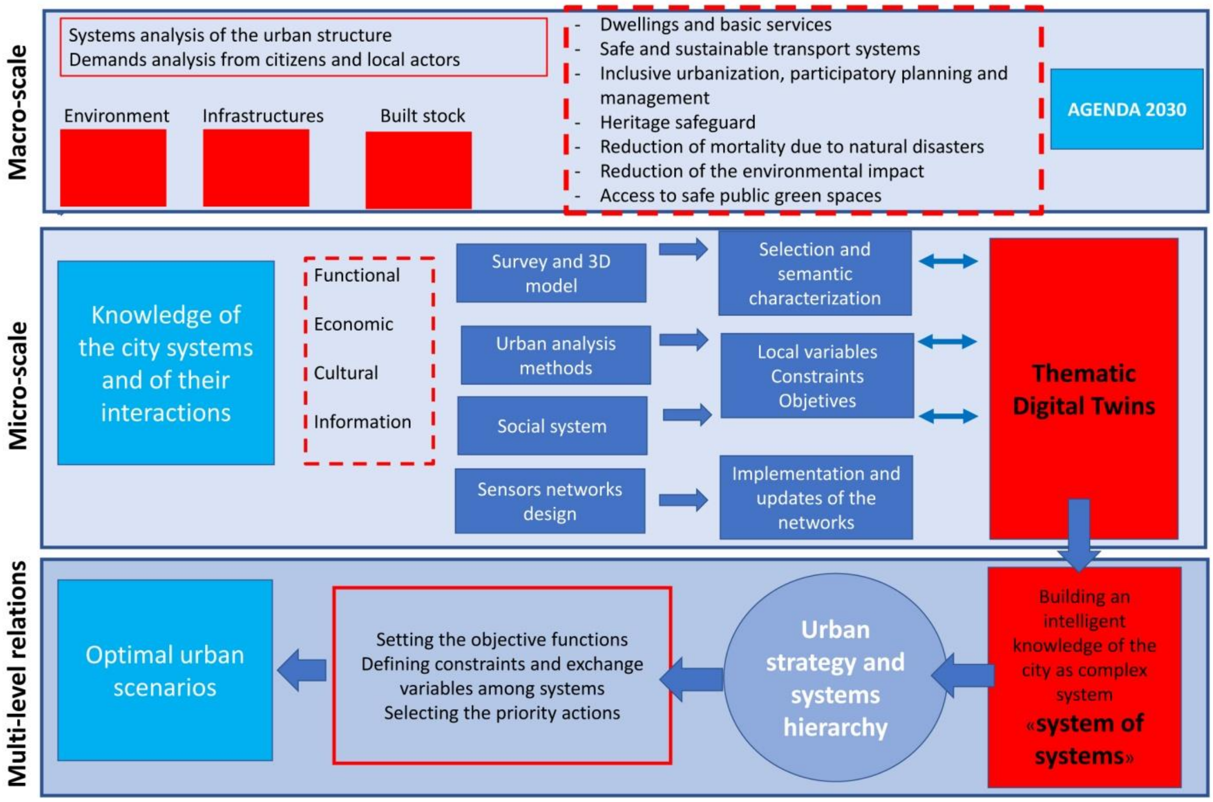
Civic participation is part of a broader multi-actor dialogue promoted by UI, which finds in the UDT a platform capable of providing simultaneously articulated, dynamic, and integrated information repositories, interfaces for comparison with the various reference groups of the local community, and multidisciplinary analysis, simulation, and decision-making tools. These resources make it possible, for the first time, to promote profound innovation in traditional urban planning practices, interweaving them with the new digital tools in such a way as to constitute a true 'cyber-urban' process, as depicted below (Castelli and Malvezzi 2022) [225].

The virtuosity of this intelligent urban planning process consists first of all in being able to manage multi-scale relations in an optimal way, both at the level of knowledge and strategic scaffolding. In particular, the construction of the process starts with the focus on the main objectives of the local urban strategy, inspired by the UN 2030 Agenda and in particular Goal 11, dedicated to "making cities and human settlements inclusive, safe, resilient and sustainable". To this general (macro-scale) focus corresponds the construction of a knowledge system pre-oriented by these objectives and aimed at deepening all the thematic levels of the city affected by the strategy. This operation corresponds, at the level of the UDT, to the modelling and semantic characterization of the urban contexts, to the activation of an appropriate sensor network, to the collection of participatory information, and to the modelling of the thematic (sub)systems/ environments of reference.

On this basis, it is possible to carry out the first internal analyses of each thematic domain (micro-scale), with the aim of identifying for each one the web of relations and the endogenous and exogenous variables that influence their changes; thanks to this first phase of the process, it is possible to focus on the specific quality objectives to be pursued for each domain.

[225] *Castelli G., Malvezzi R., 2022, 'Urban Digital Twins: reflections and perspectives', XIII GSINU - Annual Study Day of the Italian Urban Institute, 16.12.2022 (blended event), Urbanistica Informazioni, n. 306 (special issue), pp. 502-504.*

The inter-scalar structure of the Intelligent planning process



The next phase involves constructing a complex knowledge of the city by using the intelligent (multi-disciplinary) analysis tools available to the UDT. These tools enable a better understanding of the network and dynamics of transversal influences among the different thematic domains. On this basis, it is possible to establish a possible hierarchy among (sub)systems according to the general strategic objectives, and to formulate an overall urban strategy that coordinates the quality objectives identified for each domain. In this phase, a multi-level perspective is adopted, in which different possible sets of priority actions are tested, based on different systems of constraints and exchange variables between the systems (micro-scale).

This allows for the development of alternative integrated urban scenarios that may produce different outcomes with respect to the macro-scale objectives and the indicators used to describe them. The comparison between the different options can guide the PA and, in general, the network involved in the urban governance to select the optimal scenario and, on this basis, to finalise its urban strategy by defining priority actions, hierarchies and the corresponding constraints within the system.

The intelligent planning process also uses the UDT as a powerful monitoring tool for implementing the plan or the strategy, thanks to the availability of synchronous or asynchronous feedback from both the sensor networks and the established social interaction paths.

To this end, it should be emphasized that the objectives of the 2030 Agenda do not only constitute a framework for guiding the development of an urban planning process: the co-presence of general-level indicators and others of a voluntary and specific nature allows for a preliminary estimate of the quality objectives to be pursued, and thus, a careful and coherent monitoring of the effects and impacts resulting from the implementation of urban policies, both at the macro- and the micro-scale.

Thanks to this, it is possible to maintain the framework of an urban strategy, detecting in good time emerging behaviours and unforeseen reactions that are inherent to the nature of cities as complex systems, and consequently updating the instruments and implementation details initially planned. Intelligent planning is thus an adaptive process, developing through perennial cycles of self-learning that enable a governance system to find along the way the best solutions each time for the optimal pursuit of the sustainability goals.

APPENDIX

TIM Smart City Challenge

In this study, we highlighted how start-ups play a central role in Smart City-related innovation. In October 2022, TIM launched "TIM Smart City Challenge", an initiative of TIM Open Innovation to build the cities of the future together with some of the main players in the industry, innovation, and research sectors, supporting Italian municipalities and regions in adopting virtuous management models.

The challenge that TIM posed to Italian and international companies fostered the creation of an Italian Smart City ecosystem, thanks also to the collaboration with Associazione Osservatorio BikeEconomy, CNR Department of Engineering, ICT and Technologies for Energy and Transport - DIITET, Edison NEXT, eFM, Intesa Sanpaolo Innovation Center, Startup Intelligence Observatory Politecnico di Milano - Department of Management Engineering.

The collaboration with other partners aims to join forces with the main players in the Smart City field in order to encourage and further accelerate the transformation path of Italian cities towards the cities of the future, thanks to the experience and assets that can be made available to the country, enabling management models for Italian cities that thus become more easily scalable and replicable throughout the country.

The aim of TIM and its partners is to improve the portfolio of offerings for Smart Cities, to further enrich the services supporting administrations, to study the evolution of cities and to understand the needs of each individual municipality through the activation of new partnerships with innovative companies offering Smart City solutions.

In order to encourage go-to-market and scaling of the most promising solutions, TIM makes available to the Smart City ecosystem, innovative companies and its customers its experience and knowledge in the Smart City field, acquired also thanks to the implementation of the TIM Urban Genius "urban intelligence" platform in several Italian municipalities of heterogeneous size, including, for example, Venice and Cairo Montenotte an Italian municipality in the province of Savona in Liguria.

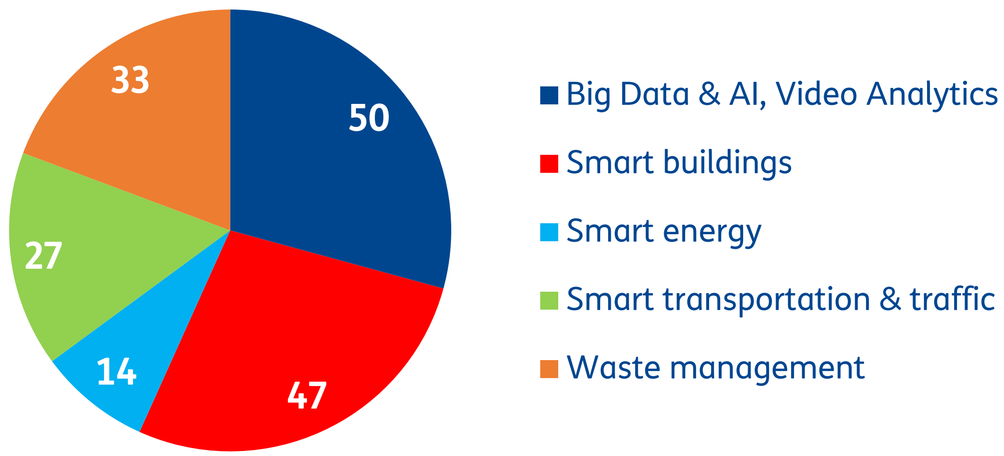
Thanks to its open nature and its ability to cover the main aspects of city management from an end-to-end perspective, TIM Urban Genius is an enabling element capable of rapidly integrating vertical third-party services, further enriching the services supporting administrations.

The results:

Through the TIM Smart City Challenge, we collected 168 applications with solutions proposed by national and/or international start-ups, SMEs, or scale-ups distributed in the following verticals:

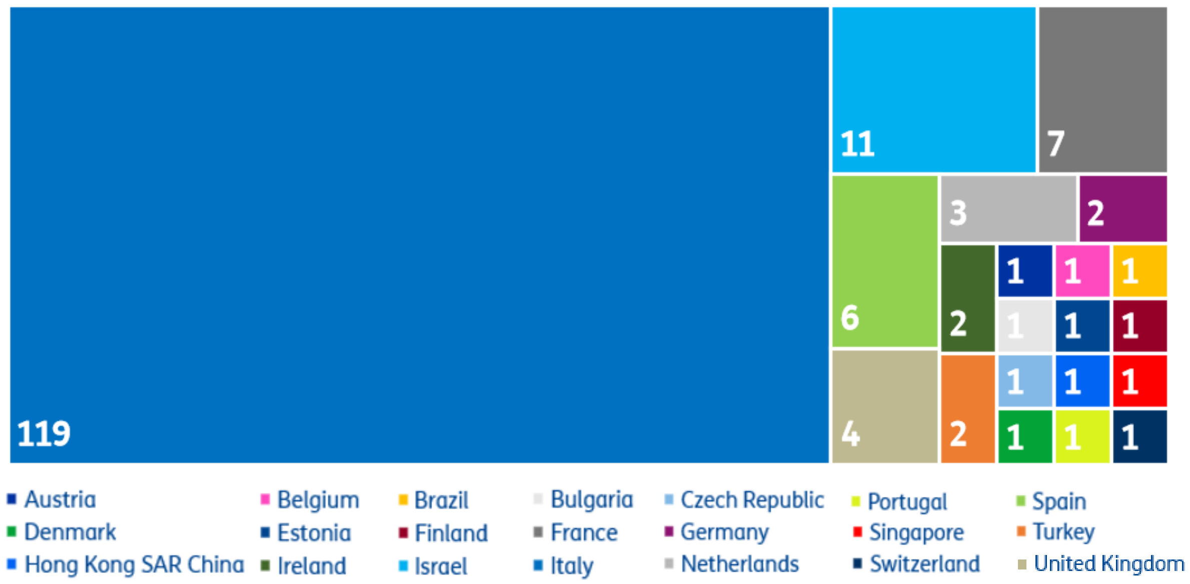
Big Data & AI, Video Analytics,
Smart transportation & traffic,
Waste management,
Smart energy,
Smart buildings.

The verticals of the solutions presented



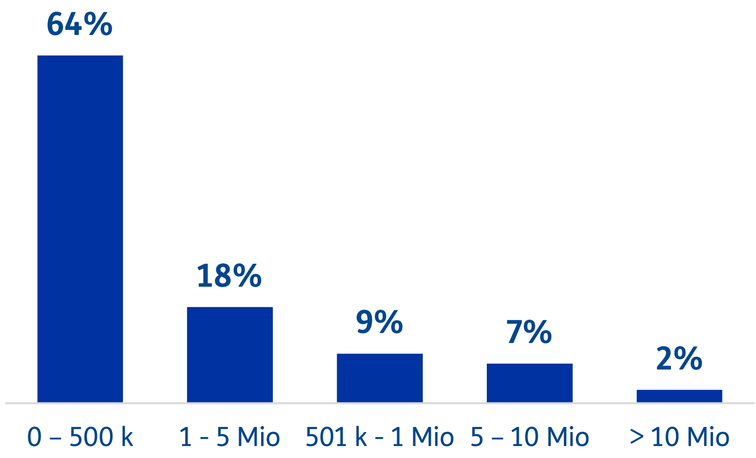
Most applications (71 per cent) come from Italy, with a strong concentration in Milan, Rome, and Turin, followed by a significant presence of Israeli, French, and Spanish companies.

The countries of origin of the Smart City Challenge candidates



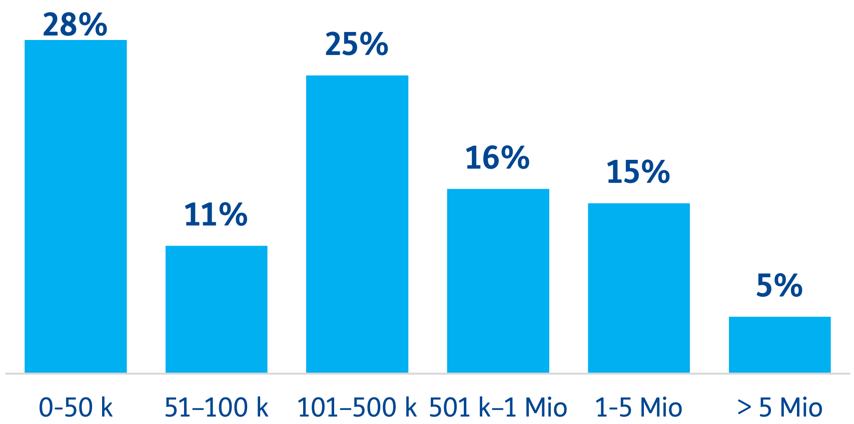
Delving into the details of the applications, 68 per cent of the start-ups with Big Data & AI and Video Analytics solutions and 82 per cent of the start-ups with Smart Transportation & Traffic solutions come from Italy and Israel, while Waste Management solutions are almost entirely from Italy except for three solutions from the Netherlands, England and Denmark.

Funding received by Smart City Challenge candidates



64 per cent of the companies received funding of up to 500,000 euros, while 27 per cent received total funding of more than 1 million euros. Of these, most are located in Italy, Israel, and France.

Turnover Classes of Smart City Challenge Candidates



Of the 32 companies that had a turnover of more than 1 million euros in the year preceding the challenge, 44 per cent offered solutions on Big Data & AI, Video Analytics, followed by 22 per cent on Smart Building solutions.

The winning start-ups:

- **Mine Crime** improves urban safety by collecting and geolocating data on crime in cities, enabling the use of prevention tools to reduce risks.

  The company has created the largest existing database on vertical crime in Europe with 27 million geolocated events and 16 thousand databases already integrated.

- **Pin Bike** promotes cycling by means of a patented system that monitors **and certifies urban cycling** trips via a sensor mounted on the bicycle.

  The system can thus verify the accuracy of the data collected for the issuance of economic incentives by mobility managers of cities, companies, and schools.

- **iMOI has developed the iCAM3D solution**, a 3D planimetric metric surveying system that simplifies the tasks involved in road accident surveying by reducing manual effort.

  It is an intuitive, instantaneous solution that allows accurate and detailed results to be obtained by simply taking a video recording of the scene and the objects involved.

- **Utwin** is a proptech start-up that **helps building owners and managers use building and asset data** digitally and sustainably, **allowing customers to cut costs and time for building management**.

  It improves building data by creating digital twins to manage all information in real time and optimise asset, facility, energy and sensor management activities.

- **Foot Analytics enables the monitoring of space utilisation within companies' offices in order to** size them correctly and **enable effective, real-time building management.**

  In this way, it is possible to have full visibility of space utilisation and quickly take improvement actions, for example in the case of under/over utilisation, **improving the employee experience and optimising running costs**.

- **G-move produces statistics on the people present in a given area** (number, dwell time, movements), **enabling it to optimise every aspect relating to the management of physical spaces**, such as shops, urban areas and means of transport.

  Using a special sensor and Wi-Fi fingerprint analysis of smartphones, the system can provide the same analytics that are popular in the world of the web, but in physical spaces.

- **Open Stage** has created a **technological totem that allows artists** to book a smart 'station' and **perform live in the city in** front of their fans.

  Using a simple app, artists can book the totem, unlock the control box with the mixer inside, connect their instruments and start the performance.

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CENTRO STUDI

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