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A Comprehensive Survey on the Societal Aspects of Smart Cities

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Abstract: Smart cities and information and communications technology is a rapidly growing field in both research and real-world implementation, but it is one that is still new and with many different ideas. Unfortunately, there is less cooperation and knowledge sharing across the field, and research often fails to move into real-world applications, which holds it back from becoming fully realized. This paper aims to provide an overview of the current state of smart cities, its definitions, technologies, and technical dimensions, from architectural design to standards and data handling, and how they are handled in the real world and its impact on society. Additionally, it examines important smart city projects, their applications, and ranking systems. This text aims to forecast the future of the field, its impact, the challenges it faces, and what should be addressed to help it reach its full potential.

Keywords: smart cities; survey; internet of things; smart city dimensions; artificial intelligence; standards; open data; big data; security; ranking

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1. Introduction

The idea of a city where technology is an integral part of the city's infrastructure to gather information to better control its environment and improve the conditions of its inhabitants can be traced back to seventeenth-century utopian fiction [1]. This closely relates to the modern concept of smart cities, which can be traced to the mid-twentieth century [2]. Although there is of yet no true consensus on the concept of smart cities, it is widely accepted that information and communication technologies (ICTs) are essential. Sensors are used to gather data, and devices communicate through a network to generate information about the city. This information can then be managed to promote the sustainable economic growth of the cities and to improve their services.

A broad range of projects developed and implemented the concept of smart cities. SmartSantander, located in Spain, has deployed a large IoT infrastructure to support various services to the city and its inhabitants (e.g., environmental monitoring, traffic management, or participatory sensing), allowing them to generate sensing data and report city issues. Moreover, the available infrastructure has been opened to third parties, allowing them to experiment with new ideas and services in a real-world environment, which might be expanded to other cities [3].

London is considered one of the leading smart cities in Europe due to its implementation of smart technologies to support a wide range of inhabitants needs, such as mobility (e.g., traffic management, public transport, smart parking, or bicycle sharing systems), city infrastructure and environment (e.g., smart grids for water and energy, smart waste

management, or pollution monitoring systems), and security (e.g., smart illumination or incident detection systems using microphones and CCTV cameras). This is achieved through extensive data collection and collation systems, which can be used to gain a better understanding of urban issues and solve them efficiently [4]. However, the most important aspect is that the London smart city actively encourages citizen participation at almost every level, from sensing to consultation to collaboration. This allows citizens to be active participants in their communities and improves communication between citizens and their governance [4,5].

A much more recent project, launched in October 2023 is the NYC Smart City Testbed Program. It serves as a platform for developers to test their projects in the real-life conditions of New York City. As one of the largest cities in the world and the largest in the United States, New York has a strong presence in smart city research [6] and has already implemented different smart solutions (e.g., waste management, lighting, or public transportation) [7].

Other established smart cities' implementations in the United States are the Chicago smart city, which presents a sensing network spread across the city that monitors various types of data in real-time (e.g., temperature, traffic, or sound intensity), and the San Francisco smart city, that municipal data (e.g., urban planning, crime, or housing) is available through the DataSF portal [8]. Data openness is considered crucial, although the city's governance needed to make significant efforts to guarantee the data maintenance [9].

Many Asian countries are also investing in smart cities. China has several cities, such as Nanjing, which aim to create an efficient transportation system, and the Sino–Singapore Nanjing Eco-Hi-Tech Island. Hangzhou has implemented the City Brain system to manage the city's traffic system, which has already shown many benefits [10]. Beijing has introduced a virtual card for its citizens, which holds their personal information, provides improved transportation options, as well as means to address the city's poor air quality. Hong Kong has invested in digital governance with the Next Generation Gov Cloud and Big Data Analytics Platform, and more [10,11].

Japan has Woven City, a smart city that aims to create a carbon-neutral environment by promoting autonomous vehicles and conditions for pedestrians. However, it is important to note that this city is owned by Toyota, and its residents have no say in its management. The objective of Woven City is to generate and test new technologies for the company, with residents serving as another source of information [12,13]. Possibly a better example is the government-sponsored smart city project of Kitakyushu City, which aims to improve environmental sustainability and find innovative solutions to energy problems. While several companies (e.g., Nippon Steel, IBM Japan, or Toshiba) are high-level stakeholders in the project, the city's municipal government also is, and the citizens' opinions and ideas are taken into consideration. This has resulted in a more effective implementation of the proposed solutions compared to other Japanese smart city projects [14].

South Korea has experience with smart cities [15], as seen in the Songdo smart city in Incheon [16] or Seoul [17]. These cities have implemented technology to improve transportation, citizens' living conditions, cultural projects, and more. One of the latest additions to smart cities in South Korea is the Busan Eco Delta Smart City. Its goals include creating twenty-eight thousand new jobs in high-tech industries, improving living conditions, which are projected to add five years to residents' life expectancy, and increasing ecological sustainability through the exclusive use of renewable energy sources and by water and waste management programs that focus on reuse and recycling [18].

Africa is home to many impoverished nations, which face a range of challenges, including lack of infrastructure, unstable governments, high populations, and economic insecurity [19]. Smart cities offer opportunities to improve all of these factors and provide a good return on investment [20]. This is why more economically and technologically advanced nations are investing in smart cities in Africa. Kigali city in Rwanda is one such city that has made use of smart technologies to improve by creating smart waste management systems emphasizing green infrastructure and ecological sustainability. The city has focused on renewable energy, sustainable public transportation, and wetlands

restoration [21]. South Africa is investing heavily in the development of smart cities, with four smart cities currently in construction. However, due to the expected completion time of twenty-five years, improvements will occur slowly over time, and complications are expected to occur over such a long period. These cities are Lanseria Smart City, African Coastal Smart City, Mooikloof Mega-City, and Durban Aerotropolis [22].

To create a smart city, a strong and well-developed infrastructure is essential. At a minimum, it is required that (i) sensors be placed throughout the city for collecting the needed data, (ii) communication networks to transmit these data, (iii) databases to store the collected data, (iv) computing resources and services to analyze and transform the available data into meaningful information, and (v) suitable applications to transform this information into added value for authorities and inhabitants.

However, technological advances have led to differences in the current implementations of these supporting infrastructures when compared to initial conceptions. First, sensors were analog devices that were part of machines they were sensing (e.g., speedometer, pressure sensor, or thermometer) and provided the status of these machines directly to human operators. However, with the introduction of ICTs, multiple sensors can now share their information with advanced control systems that allow a single user to oversee a large number of sensors. Moreover, sensors also became digital, smaller, and more energy efficient, allowing for sensor packages that collect multiple different types of data. Second, due to limitations, such as bandwidth and signal interference, the communication networks had to be wired and confined to a singular location. However, with the advent of wireless technologies, they became more affordable and widespread, enabling the use of sensors and computing devices in almost any location, which allowed for the implementation of functions that previously would be impossible or prohibitively expensive. Additionally, as wireless networks became able to provide bandwidth and throughput comparable to wired networks, it became possible to transmit significantly larger amounts of data, allowing for more complex sensing packages, which in turn opened new possibilities. For instance, the real-time monitoring of multiple health data streams (e.g., pulse, oxygen level, or glucose level) from a patient.

These advancements enable the creation of complex systems, which include multiple sensors for data collection, wireless capabilities for communication with other devices, and computing resources for storing and analyzing collected data. This is most well exemplified today by the modern smartphone, which allows for any citizen in a smart city with the appropriate infrastructure to become a mobile sensor for that city. This is also at the root of the Internet of Things (IoT) concept, which involves integrating sensors into everyday objects and enabling them to connect to the internet to share the data collected, which facilitates the acquisition of detailed data, namely from previously unavailable sources, and thus enables more accurate problem prevention and resolution [23,24].

Advances in the gathering of data from multiple sources are being accompanied by advances in data storage and analysis. In terms of data storage, relational databases are commonly used to store large volumes of data on digital systems, but the massive amounts of data generated by smart cities make them unsuited for the task of retrieving that data even if they can store it without issues. This is because they are designed to perform create, read, update, and delete (CRUD) operations on small amounts of data [25], and due to having to import data into their native format, they have problems with real-time data [26]. This becomes the domain of big data technologies, such as NoSQL databases, which are non-relational and thus allow for vastly increased speeds. Additionally, data warehouses of various types, such as the massively parallel processing (MPP) databases, which coordinate multiple operations in multiple hardware devices in parallel, also allow for much improved efficiency [27,28].

Moreover, concerning data analysis, machine learning (ML) and artificial intelligence (AI) can efficiently search through vast amounts of data to quickly identify previously unseen patterns and automate tasks. For instance, it can be used to monitor traffic conditions in a city and automatically implement changes to improve traffic flow [29].

As technology has progressed, the focus has shifted from creating better hardware and providing the necessary infrastructures to improve the required software to handle the massive amounts of data generated, to provide services with impact in people's lives, and to integrate them in the smart cities' ecosystems. This last aspect represents a huge challenge that assumes a great importance to avoid dehumanization or giving more importance to the technological goals of the smart cities than the effective needs of their inhabitants. As a result, there has been a refinement of the purposes of smart cities by emphasizing the perspectives of their inhabitants, which is a crucial strategy to translate the predicted sustainable economic growth of the smart cities into improvements of their inhabitants' quality of life [30,31].

It is worth noting that while smart cities can have a significant impact on various aspects that affect the quality of life of their citizens (e.g., safety, environment, or health conditions), even the most advanced adopters have not fully realized their potential and still have much work to accomplish [32]. However, all over the world, there are smart cities' projects whose implementations in real-world environments, become part of the body of knowledge that might be used as a foundation for other implementations.

Smart cities are an incredibly complex endeavor and thus difficult to implement. They have different requirements according to each city's needs, services, and infrastructure, which are essential in one city may be irrelevant in another. For example, a city located in a hot environment would require infrastructure to help conserve water, while another in a humid environment would require infrastructure to prevent flooding. Any aspect of a city that can be enhanced by smart city technology can be implemented differently depending on each city's necessities, environs, and priorities. Furthermore, there is the human element to consider. A smart city's governance would ostensibly be performed by the public government of a city. However, they are not the only stakeholders who have an interest in the governance of a smart city [33]. Due to the cost and complexity of implementing a smart city, governments may require financial help from private companies and industries, research and technological assistance from universities and research institutions, and negotiate and achieve compromises with other cities' governments [34]. All these entities have a stake in the smart city and have interests they will want fulfilled, and thus will want to have a voice in the decision-making process [35]. Furthermore, all these systems once implemented will have to work in conjunction with each other, and the data collected will have to be analyzed and used without compromising the security and privacy of the citizenry. This will require even more systems (e.g., middleware, AI, and security), which will increase the complexity even more. This complexity is why implementing smart cities is so difficult, and thus it is important to define each dimension of a smart city and how they can be implemented and the stakeholders appeased.

Considering all these recent developments, several surveys were published focusing on specific aspects related to the implementation of smart cities, such as the application domains of smart cities [36,37], the role of disruptive technologies (e.g., IoT, blockchain technology, or big data) [38], the application of IoT [39–43], blockchain technology [44,45], machine learning and artificial intelligence [46–48], multi-agents [49], fog computing [50], edge computing [51], open data [52], federated learning [53], the use of crowdsensing [54] data analytics [55–57], the systematization of privacy and security issues [58], or the proposal of a research agenda for public–private partnerships [59]. In turn, this article reports a survey of the dimensions of interest for a city and how smart city technologies can be applied to these dimensions to improve them. Subsequently, we present these technologies and how they are used, as well as their advantages and disadvantages. An additional topic will be how to classify and rank smart cities. In this article, we aim to show that smart cities and their associated technologies are still in their infancy when it comes to implementation in a real-world environment and that the field has various challenges to overcome, namely in how research is still very insular and there is not sufficient knowledge sharing, and there is a lack in the uniformization and standardization of that knowledge into a consistent base from which to progress, and the difficulty to transition from research

endeavors to real-world applications. Additionally, most other reviews focus on the technical and technological aspects of a smart city, while our review aims to show how smart cities can impact society and the lives of their citizens. For example, a survey of IoT in smart cities delves into many of the same areas we explore (e.g., transportation, healthcare, and energy) but instead focuses on the technologies of a smart city, like sensors (e.g., chemical, bio, and motion) or network protocols (e.g., Bluetooth, Wi-Fi, and ZigBee), and how these technologies can be applied to those areas to implement smart solutions, but it does not explore how these technologies impact the society and its citizens where they are implemented [39]. It is quite easy to find many surveys of the same type in the literature, such as one that focuses on how smart technologies can be used to create floating cities [60], another that delves into how big data and data mining can be used on smart cites [57], and another into the algorithms used in smart city applications [61], with all of them focusing on the technological aspects with only a passing mention to the societal aspects. However, studies that focus on or mention in some detail the societal aspects of smart cities are much harder to find. Our paper focuses more on how these technologies affect society and on the current state of smart city research and how it is conducted. Furthermore, it needs to be stated that there is nothing wrong with the surveys, which focus on the technical aspects, and that our paper aims to cover an aspect of the research that is lacking in the current literature.

The article is divided into six sections. Section two discusses the most accepted dimensions of a smart city, as shown in Figure 1, while section three explores different areas of smart city technologies, from architectural designs, standards, open data, internet of things, big data, artificial intelligence, and security, as show in Figure 2. In section four, various methods for ranking smart cities are discussed. Section five addresses the challenges that affect smart cities and what the future may hold for them according to current trends. Finally, section six concludes this paper by summarizing the presented information and key learning points.

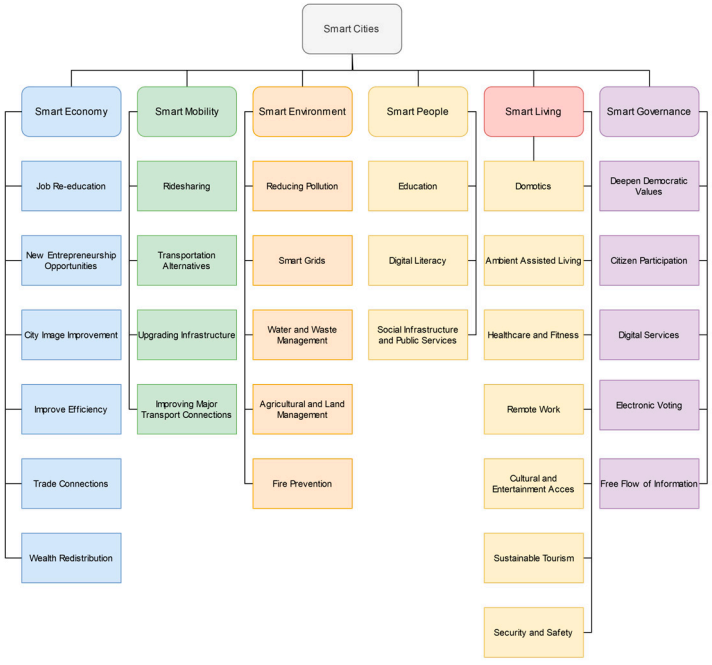

Figure 1. Smart city dimensions and applications.

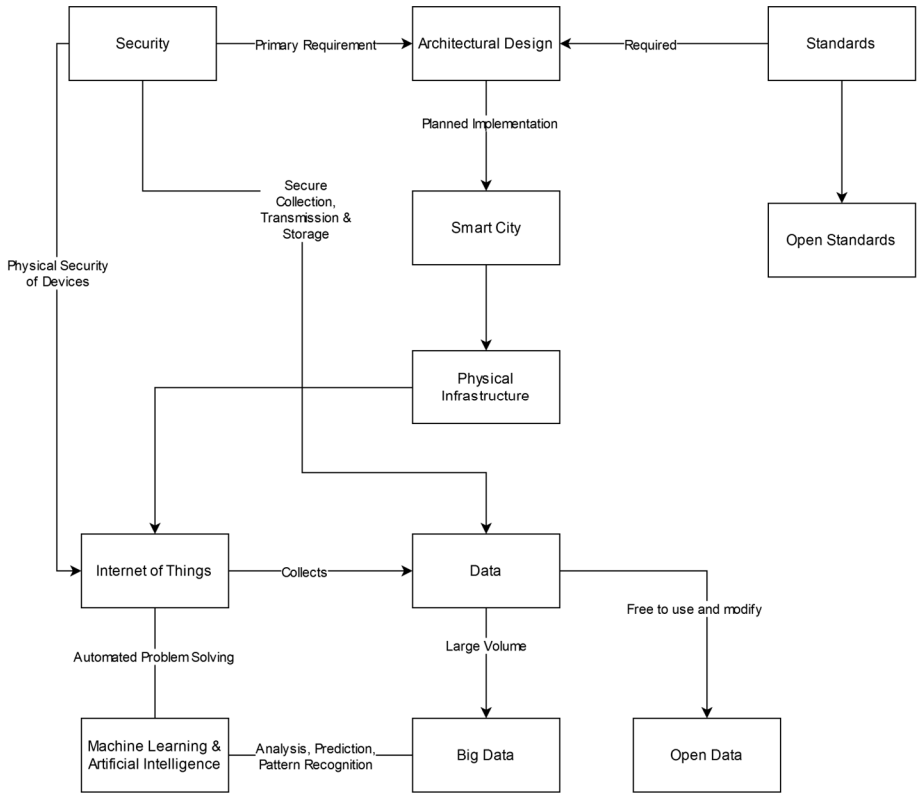

Figure 2. Smart cities technology interactions and dependencies.

2. Smart Cities Dimensions

Since smart cities have different objectives, their implementations might differ significantly. Despite this disparity, there is a common understanding of the crucial functions of every city. This gave rise to the concept of smart city dimensions, which comprise distinct areas of interest in a city (e.g., energy, environment, or culture) that can be improved using smart city technologies. Although more dimensions exist [62], the most commonly utilized are the following six dimensions [63,64]: (i) Smart Economy; (ii) Smart Mobility; (iii) Smart Environment; (iv) Smart People; (v) Smart Living; and (vi) Smart Governance. As can be seen in Table 1, each of these dimensions is composed of several domains to be acted upon.

Table 1. Smart city dimensions.

Dimensions	Domains
Smart Economy	Innovative spirit Entrepreneurship City image Productivity Labour market International integration
Smart Mobility	Local transport system (Inter-)national accessibility ICT infrastructure Sustainability of the transport system
Smart Environment	Air quality (no pollution) Ecological awareness Sustainable resource management

Table 1. *Cont.*

Dimensions	Domains
Smart People	Education Lifelong learning Ethnic plurality Open-mindedness
Smart Living	Cultural and leisure facilities Health conditions Individual security Housing quality Education facilities Touristic attractiveness Social cohesion
Smart Governance	Political awareness Public and social services Efficient and transparent administration

Note. Adapted from Giffinger. Rudolf; Kramar, Hans; Haindlmaier, Gudrun; Strohmayer, Florian European Smart Cities 4.0 (2015). Available online: European Smart Cities 4.0 [65] (accessed on 1 April 2024). Copyright 2015 by TU Wien.

2.1. Smart Economy

The understanding and characteristic of economy evolved over time (e.g., market-based, state-controlled, or green economy). However, since the first civilizations, economy comprises the practices that enable the production, use, and management of resources [66]. Throughout human history, many civilizations shared the belief that the natural world and its resources were inexhaustible and infinitely replenishable, despite evidence to the contrary. It was in fact only as recently as the nineteenth century that this notion began to be challenged, and nations became aware of the importance of measures to preserve and maintain their natural resources. However, it was only in the mid-20th century that it was realized that human activity was damaging the planet faster than it could repair itself and that there was a need for drastic changes in the way humans interact with the environment.

It was from this reasoning that the concept of sustainable or green economy (i.e., the improvement of the "well-being and social equity, while significantly reducing environmental risks and ecological scarcities" [67]) was conceptualized. In short, a successful green economy must provide economic growth while preserving ecosystems and resources, minimize pollution and assuring the population needs [68]. Its ultimate goal is the homeostasis with the environment, allowing both to continue indefinitely, barring outside intervention. However, given the ecological damage that has already sustained, it is necessary to make active efforts to reverse this damage and minimize the impact and the duration of its consequences.

Due to their large populations, cities are significant economic drivers but are also one of the major contributors to ecological damage, both directly and indirectly. In this respect, it is foreseen that smart technologies might reduce the cities' impact on the environment while assuring the economic development, which is the basis of the smart economy concept. But how can this be achieved?

It is commonly accepted that innovation is a central tenet of a smart economy, and any economic costs that are incurred by investing in innovation will have significant returns not only in economic terms but also in terms of environmental preservation and societal improvement. However, when new technologies are introduced, there is often a fear that they will replace human jobs. This concern is not new, as demonstrated by the Luddites in the nineteen century, who rioted and destroyed textile machines out of fear that they would replace them. Although similar incidents had occurred before, this particular event had a significant impact on society, and today the term Luddite refers to someone who opposes new technologies and the changes they bring [69]. However, it has been proven

that in the grand scheme of the labor market, technological innovation creates more jobs than it destroys. Denying this fact is known as the "Luddite fallacy" [70].

It is, however, important to exercise caution when adopting new technologies. While innovation can bring benefits, it can also render previously lucrative enterprises unnecessary or unprofitable, resulting in job losses and resentment. They can also lead to job losses for those who are unqualified for the new roles that emerge. This was the actual concern of the original Luddites, rather than the machines themselves. However, it is important to acknowledge that people today are generally better educated than those in the nineteenth century. If a wide acceptance of new technologies is to be achieved, it is crucial to consider the needs of those who may be displaced by them.

Since new jobs require well-educated individuals, cities should provide financial compensation and comprehensive education programs, potentially supported by smart technologies [21,71], that effectively cover digital technologies in addition to standard curricula. The aim is to educate the citizens, who will be able to enter the workforce fully prepared, and re-educate and retrain older citizens to enable their participation in the workforce and for both to be able to use the new services provided by a smart city [72,73]. This is not only an ethical matter, which by itself should be enough of a reason for implementation of these measures, but also an economic one. By providing individuals with the means to re-enter the job market, they can become a net positive to the economy by providing labor and by becoming consumers.

Smart technologies also provide new ways for entrepreneurship and give rise to new enterprises and to new ways on how to manage and run them. Enterprises such as Startup Compete, Kickstarter, Uber, Lyft, or Airbnb are entirely predicated on digital technologies and the availability and understanding of these technologies to the public. They allow for new ways for entrepreneurs to present their ideas and gather funding (e.g., Startup Compete or Kickstarter), the availability of transportation practically anywhere (e.g., Uber or Lyft), and accessible hospitality services (e.g., Airbnb) [74]. These services are achieved by a much more direct interaction between clients and providers, which improves their efficiency and availability.

Improving productivity and efficiency of processes is one of the cornerstones of ICTs and smart technologies; as such, smart cities naturally also see impacts in these areas, even if that is not the main objective. Automation of processes, remote work and digital workspaces, and ubiquitous access to the internet and its resources have changed how offices work and increased the productivity of their workers, although, it has also allowed for cyberslacking, which reduces productivity [75]. Smart factories integrate these technologies so that the machinery of a factory can become even more automated, capable of self-diagnostic and repair, work with institutions outside the factory (e.g., distribution, markets, and suppliers), and adjust production with minimal human intervention [76]. Human workers would assume a more managerial and decision-making position over their equipment. But the productivity changes can be seen in more than the workplace; improvements on a city's transportation systems help users save time; the increased efficiency of a smart grid provides more energy at the same cost; and increased quality of life improves citizens' morale. All these benefits improve productivity in small but cumulative ways, which leads to economic growth [77]. These, while important, are but one way to improve economic growth.

All cities have an image they project to the world, with positives (e.g., cultural hub, industrial powerhouse, or learning campus) and negatives (e.g., corrupt, polluted, or crime). When a city tries to become a smart city, it is a chance to change that image for the better. A smart city by itself already projects an image of technological advancement [78], but by implementing certain types of projects, it is possible to enhance the positives and to handle the negatives. By, for example, improving security [79], investing in green technologies [80], or improving city infrastructure and services with smart technologies [81], a city's image is also improved. This makes the city more attractive for new residents and investors, as well as a more attractive trading partner and tourist destination.

No man is an island, and the same can be said of cities. Without connections with other places, a city will suffer, see its economic and growth potential stagnate, and in the worst case, disappear entirely. Therefore, connecting with other cities is a key aspect for good economic conditions [82]. This can be achieved by closer integration of infrastructure and information between cities. Integrating different research institutions enables research problems to be tackled with different perspectives and more options [83] and also allows for the results to be spread widely much faster and thus more quickly implemented. Furthermore, by integrating processes and infrastructures, it allows for outside companies to more readily invest in a city due to the increased ease of trading, entering a foreign market, and making use of local infrastructures [84,85]. In this respect, to increase the required truthfulness of the interactions, blockchain has also been used to provide improvements on organizational performance [86].

All of this brings us to the concept of a digital economy, where more and more the traditional components of the economy are transformed or replaced by ICTs. Traditional brick-and-mortar stores are replaced by digital stores on the Internet, people use remote work instead of physical offices, advertising moves from traditional venues to websites and social media, and the sale of fully digital products (e.g., e-books and video games) and services [87].

The advent of the digital economy has made the storage of large quantities and varieties of products even more of a necessity than before. Smart warehousing is used to improve what used to be a necessary cost in the production chain but is now considered essential. Modern warehouses are not limited to storing products but are also the location where those products are distributed from. Smart tracking of inventory through RFID and automated decision-making systems and using algorithms to determine storage location of products to maximize space allocation and minimize retrieval time enable efficient operations at reduced costs. Additionally, robotic and automated systems also allow for automation of labor-intensive tasks, such as the loading and unloading of products and their retrieval and storage in inventory [88,89].

Finally, it is important to have laws and institutions in place because revenue-generating companies aim to be profitable rather than serve the public good. It must be understood that this is not to be taken as a negative or a positive, but simply as a statement of fact. In a future where automation has made human labor redundant, then the economy shifts from one of scarcity to one where the distribution of wealth is the main problem. In this society, individuals no longer have the power to distribute wealth through their labor, resulting in wealth being concentrated among a select few (e.g., companies, corporations, or governments). While it may seem that those few would have no issue distributing their vast wealth to the masses, historical evidence and the rise of income inequality suggest otherwise unless proper measures are taken [90,91].

2.2. Smart Mobility

Mobility is a crucial concern for urban residents, as different services are geographically distributed. This is particularly significant for those in lower income brackets, for whom a reliable and affordable public transportation system can improve job availability, access to services, and overall quality of life. Public transport systems also help to reduce the number of cars circulating, easing traffic congestion, and reducing carbon emissions and air pollution.

Therefore, improving mobility is a key aspect of smart cities. Enabling efficient movement of people and vehicles provides inhabitants with better access to city services, job opportunities, and intercity trade. This can be achieved through various strategies, including but not limited to the development of a reliable public transportation system, the provision of real-time transit information, smart traffic signals, and the use of autonomous vehicles. Specifically, services such as Uber or Lyft enable individuals to request a ride from a pool of drivers using their personal vehicles or to become drivers themselves. Self-driving cars are another technology that could significantly impact mobility in cities; however, to

achieve full autonomy, they require not only adequate computing resources but also the support of a smart city's infrastructure [92].

Travel in cities is not limited to traditional motorized vehicles, which means that the cities' infrastructures should be restructured to accommodate non-motorized vehicles (e.g., footpaths, bicycles' lanes, or bicycles' sharing), as already happens in many of them, since cycling is a common transportation modality in many countries across the world, with some (e.g., the Netherlands or Denmark) relying on it as their primary mode of transportation [93]. However, cycling requires widespread networks of vehicle charging/parking stations as well as bicycle paths that allow users access to a wide range of destinations, which often requires expensive and time-consuming restructuring of a city's layout.

Nevertheless, this restructuring is part of the effort of smart cities to decrease their transportation environmental footprint by focusing on electric vehicles, public transportation, and other non-polluting alternatives, and thus already being implemented and expected to continue and accelerate into the future [94–96].

Under the remit of smart mobility is included the building, upgrading, and maintenance of the transport infrastructures. Creating new types of roads that offer advantages over traditional paved roads, such as solar roads, which are composed of photovoltaic panels and would produce electrical energy all through the day, or plastic roads, which would be built not out of asphalt but of plastic [97]. In turn, several components of the mobility infrastructure can also be upgraded, such as, for example, smart signage that informs users of accidents on the road, automatic lighting that can turn off when there are no vehicles, and direct monitoring of important infrastructure (e.g., bridges, railway crossings, or pedestrian crossings) [98–100]. Moreover, maintenance can also be improved by allowing the citizens to report issues using digital applications, which enables the authorities to allocate maintenance crews to problem spots as soon as they appear and prioritize according to need [101].

However, roads and the vehicles that use them are not the only ways smart mobility applies to cities. For cities that have them, seaports and airports are major connections for national and international trade and tourism. However, managing such critical structures and the traffic they generate is not easy, requiring skilled labor and complex infrastructure. Therefore, applying smart technologies to them can bring great benefits. From, among others, creating systems to optimize airplane routes, landing and takeoff schedules, automated maintenance scheduling, and sensors to detect faults. Seaports can also benefit from systems to optimize berth allocation, route planning, and the loading and unloading of cargo. These and other improvements for air and seaports reduce costs, improve safety, help the environment, and improve passenger satisfaction [102–104].

2.3. Smart Environment

One of the key motivators for implementing smart cities is the environment. Urban populations have been steadily increasing throughout the twentieth century. In 2010, almost 52 percent of the world's population resided in urban areas, and this number is predicted to rise to over 68 percent of the population by 2050 [105]. Therefore, urban areas are responsible for 70 percent of the world's carbon emissions [106,107] and will be severely affected by the effects of climate change. In fact, without even considering the knock-on effects of climate change, cities are at direct risk of destruction by the rising sea levels since most cities were built on or near coasts or rivers. Therefore, cities should improve their infrastructure by implementing smart technologies such as smart street lighting that adjusts to light conditions to curtail waste, smart meters for energy and water, sensors to detect leaks, smart irrigation, smart bins that notify when they are full, and more [108–110].

In the context of smart cities, the smart environment dimension includes the implementation of new services to turn cities more sustainable with healthier populations while guaranteeing economic development without sacrificing the environment [111]. For instance, air pollution has a significant impact on the health conditions of the cities' inhabitants, reducing their life expectancy and their quality of life. Systems exist that allow for

accurate monitoring of air quality, which enable authorities to enact measures to curtail pollution sources [112,113].

Additionally, one of the ways for a city to increase its environmental sustainability is by upgrading its electrical grid to a smart grid. Smart grids are focused on the use of non-polluting, less environmentally impactful, and renewable energies and aim to maximize efficiency by coordinating the production and use of stored energy to meet consumer demand, allowing for the integration of both centralized and distributed energy production grids [114,115].

Considering the cities' surrounding environments, it is important to safeguard the linking of remote areas to the national energy grid, both to provide electrical power to remote villages and to harness remote, but high-energy production locations (e.g., mountain wind farms, island wave generators, or desert solar farms). Systems exist for local energy generation as an alternative or backup to the power grid in case of unexpected occurrences, which may take time to repair due to remoteness and low priority [116,117]. These, and larger energy generation systems, can be monitored using IoT, resulting in better efficiency, lower costs, and better information availability despite remoteness [118,119].

In turn, water management services require the monitoring of drinking water quality from local sources (e.g., artesian wells or communal fountains), rivers for pollutants, and flood warnings. Sensing systems are available for remote water monitoring in both large bodies of water (e.g., rivers, lakes, or dams) and smaller ones (e.g., wells or water tanks) [120,121].

Moreover, smart environment technologies also include agricultural management of land and animals to maximize production without depleting natural resources and to prevent encroachment on natural habitats and wildlife. There are management systems that utilize IoT to improve or perform various tasks (e.g., weeding, irrigation, or monitoring of soil conditions), which help to increase yields, reduce costs and improve the sustainability of agriculture [122]. Possible examples include systems to manage irrigation and decrease waste, as agriculture is the biggest user of freshwater globally [123,124], or systems to monitor wildlife both to minimize damage to agriculture caused by wildlife and to reduce human impact on wildlife [125,126].

Additionally, heavily forested areas are more susceptible to fires, which can be difficult to detect and extinguish before reaching dangerous proportions due their remote and inaccessible locations. Systems can be produced that use sensor networks to detect the early signs of a fire enabling prompt action to extinguish the fire. Even if that is not possible, they still provide invaluable information as they allow firefighters to remotely monitor fire progression and issue early warnings to both teams on the field and threatened populations [127–129].

2.4. Smart People

As proposed by Abraham Maslow, human beings have various physiological and psychological needs that must be met in order to achieve personal growth and a stable life [130]. When designing smart systems, it is important to consider these abstract human elements in addition to efficiency and effectiveness factors. Any type of smart system might interact with human beings, sometimes only tangentially, other times to support their lives and well-being, contributing to a healthier, more knowledgeable, and overall developed society.

An important aspect is the level of education of a population and how ICTs can be used to enhance education. This includes not only formal education but also education and sensibilization campaigns, such as the one implemented by India to improve their sanitation situation [131]. Education should also include measures to improve digital literacy [132] and surpass the digital divide, which separates people who are digitally literate from those who are not. Like traditional literacy, being digitally illiterate precludes a person from taking part in many activities and closes options to them. This contributes to the digital divide, which occurs both when an individual lacks the knowledge and skills necessary to

effectively use ICTs despite having the necessary equipment or when an individual lacks access to either parts or the whole of the infrastructure required for the proper use of ICTs. This divide is more prevalent among individuals with lower socioeconomic status and communities with inadequate infrastructure [133].

Any individual is a valuable addition to whatever community it is part of with their skills and knowledge of the possibilities available in a smart society. However, this comes with costs, as a society is required to develop and maintain the infrastructure required for all levels of education and also the ICT infrastructures to enable the smartness of the community as well as public services available and easily accessible to all (e.g., public transportation, welfare services, or sanitation). Good social safety nets allow for integration (e.g., social, economic, cultural) of different groups of people and allow for personal growth (e.g., cultural, economic, or creative) and social mobility. However, these costs are necessary and constitute a challenge that any city or community government must consider [134,135].

However smart education in the long run brings costs down, by helping teachers automate administrative tasks (e.g., attendance and evaluation), allowing teachers to focus on teaching, and by allowing new forms of teaching adapted to digital environments. These digital environments also allow students to learn at their own pace and for distance learning to become possible and practical both for students in remote locations and during major events, like the COVID-19 pandemic. Additionally, it allows for enhancements in student transportation, health monitoring, campus security and energy management, improving the performance and quality of life of students, teachers, and the school facilities without increasing costs [136,137].

2.5. Smart Living

Globally, industrialization increased living standards since governments had invested in infrastructure and services, and the general population could afford to spend more money on better housing, amenities (e.g., appliances or cars), and education. Moreover, the increasing prevalence of ICTs in everyday objects is changing the ways people live (i.e., smart living).

For instance, the development of domotics or home automation might transform a regular house into a smart house by adding a level of intelligence and automation to daily activities (e.g., food preparation, temperature regulation, or lighting). The goal is to reduce the workload of people, provide better efficiency, lower costs, and promote sustainability. Home automation has advanced rapidly from its origins in university research [138] to a rapidly growing market where multiple companies compete for market share [139,140]. However, despite its rapid growth, the field is still a young one, which means several problems persist. Competition between companies can lead to rapid technological progress, but this may not always benefit the consumer. Companies often create their own technical standards for their equipment instead of adopting a universal one that can be used by everyone. This market fragmentation might turn a customer entirely dependent on their chosen company, and their purchased equipment could be rendered useless if the company goes out of business, discontinues support for older equipment, or charges customers for continued use [141]. These issues could be solved by enacting new consumer protection laws and by implementing universal technical standards, which are fundamental as smart homes become more prevalent and able to make use of vast energy resources in the form of solar and wind power, even in places where a power grid does not exist [142].

One issue that affects both developed and developing countries and that smart homes can help mitigate is the population aging. The proportion of older people in a population is growing, and it is expected that by 2050, one in six people will be 65 years of age or older. This trend was first seen in developed countries, but today practically every country in the world is experiencing it [143]. Ambient assisted living (AAL) solutions synergize excellently with smart home systems because these can automate many day-to-day tasks and, therefore, can greatly benefit older adults and those with physical or mental impairments, which can signify the difference between living independently in their own home or having to be

cared for, for example, in a nursing home. To ensure the needs of its occupants are met, a smart house designed for older adults must be able to monitor and handle their physical, mental, and social needs [144]. For that, one of the biggest research challenges is activity recognition. The definition of activity is broad, encompassing any action a person can perform, and as such, making an ICT system recognize something that to a human would be a simple activity (e.g., walking, picking up something, or sleeping) can be challenging and requires a combination of hardware and software [145]. AAL systems are of great use for people with health problems but are not the only smart technologies that can be applied to health.

In healthcare, a common saying is that an ounce of prevention is worth a pound of cure, and smart technologies can be highly effective in achieving this goal. Health and fitness apps allow for individuals to track their personal health regimens, while remote monitoring enables physicians to detect early symptoms of a disease. Moreover, monitoring of city conditions (e.g., air, water, or soil quality), automatic emergency alerts, and analysis of inhabitants' data can help identify and address populations' health conditions.

Smart living and the respective supporting technologies also have a profound impact on the way people work. Telework or working from home is something that has been planned for and implemented for some decades already, although it was not the norm for the majority of the workforce [146,147]. However, due to the COVID-19 pandemic, telework has surged to prominence almost overnight and has become an established normal work option to some extent [148]. Although telework has proven to be a means for work to be able to continue even during a global pandemic and as a way to minimize the spread of the disease, its sudden leap in relevance means that it must be tested against regular working conditions to evaluate its positive and negative aspects (e.g., efficiency, burnout rates, job satisfaction, promotion prospects, or work–life balance) [149].

Additionally, as there is more to life than just work it is necessary to consider how people have access to entertainment and cultural venues. Smart cities have focused on creating green spaces that are mobility-friendly, enabling all its citizens to experience them, as well as areas for sport and exercise [150]. Cultural projects have left the enclosure of physical buildings, like museums, to be integrated into the city itself for all to experience. Additionally, collections of artifacts and books have been digitized and made accessible, virtually, so that anyone can explore them. These initiatives promote integration, increase citizens' well-being, and provide a common cultural identity, which increases social cohesion [151,152].

Moreover, these initiatives also have the side effect of making a city more attractive to tourists, with sport and cultural festivals and initiatives being of interest to people seeking to experience other culture and locations. Therefore, when handling tourism a smart city might implement measures to manage tourists, which allow both them and the city's population to enjoy themselves. Having accessible digital resources that promote lesser-known locations, inform peak times and capacity, and other resources allows for tourists to better manage their time and reduce their impact on the city. Additionally, cities can employ systems to fight illegal activities, such as illegal apartment rentals. These measures help combat overtourism and allow for a more sustainable tourism industry [153,154].

Finally, security and safety are factors that impact a citizen's quality of life in significant ways, and any improvement can have a major impact not only on quality of life but also, and more importantly, on lives saved. Data collection and analysis can be used to create real-time and historical crime maps, improving the efficiency of emergency services responses and allowing for a more efficient use of resources. Early warning systems can drastically reduce mortality and secondary damages during disasters. Additionally, a city sensor network, coupled with home security systems, can detect and inform authorities about crimes in real-time.

2.6. Smart Governance

Various governments already provide online services to allow citizens to perform tasks that previously required face-to-face interaction, with some being completely switched to online-only.

However, ICT services might also be used to deepen democratic values. As settlements develop from villages to towns to cities and to modern-day metropolises, it becomes increasingly difficult for citizens, especially those with lower socio-economic status, to make their voices heard by authorities. This presents a problem for a city's authorities administrations, since without understanding the needs of their citizens, a lot of time and resources can be wasted on projects and infrastructure that are inefficient, unwanted, or just unnecessary, which leads to dissatisfaction from a city's population. As such, they require a way to gather information about the needs and wants of their citizens.

Citizen participation is a necessary component of a strong democracy, but even more autocratic governments disregard their citizens' problems and opinions at their own peril. Smart city technologies enable citizens to share their ideas and problems directly with their city's governance much more easily. Possible examples are the SmartCitizen app [155], which offers a mobile social network (MSN) platform for its users, and the Smarticipate platform, which aims to enable citizens to participate directly in the planning and management of their city [156]. This type of application allows cities' authorities to accurately assess citizens' sentiment and to easily ascertain which problems are more preeminent and prioritize resources accordingly. Moreover, a city can also create a mobile sensing network at a cost comparable to that of implementing and hosting a mobile application and curating the data collected. This network can complement the city's regular network, providing a more comprehensive picture of the city's status [157].

In a representative democracy, individuals do not actively participate in policymaking, instead voting to elect representatives, who will represent them and their like-minded peers in a forum with the representatives of the other opposing ideas. This allows for all groups with views on an issue, even minority ones, to have a say in how policy is enacted, while still enabling for speedy resolution even in large populations, but has several inherent weaknesses [158–160]. For instance: (i) elected officials are individuals and thus, if not properly safeguarded by laws, may enact policies that serve their own interests rather than the needs of the people; (ii) it is easier for individuals or minority groups with significant power (e.g., economic, social, or religious) to use it to influence officials to enact policies that benefit them rather than the rest of society, a considerably harder proposition in a direct democracy, ironically due to the large number of people involved; (iii) partisanship can occur, where people support their group and their policies independently of their effects and can result in a lack of compromise between groups. It can also lead to situations where only a few or, in extreme cases, one of those groups has any real power; (iv) the people and elected officials ignoring critical issues or being manipulated to do so due to the overwhelming amount of information that is often difficult to comprehend and process and may cause people to fail to actually reach a decision or be unable to understand all the options available.

Smart governance and related concepts such as eGovernment or eDemocracy combine the use of ICTs with government processes to surpass the representativeness difficulties and to improve transparency [161]. The objective is to bridge the gap between a representative democracy and a direct democracy by combining their advantages while minimizing or eliminating their disadvantages. One way to achieve this is by creating digital spaces where citizens can participate in active discussions of issues. These spaces can be either informal, where people discuss issues to remain informed and learn about them and of the opinions of others, or governmental, where the discussion is actively monitored by government officials so as to understand public opinion and use it to implement policy [162]. Both types of forums require correct and current information, impartial moderation to maintain rigor and efficiency, and a robust security framework to protect the privacy of the users and their data. However, a governmental one has additional requirements [161,163], such

as (i) ensuring that citizens have the means and the technical knowledge to participate, (ii) informing citizens of how and where they can participate, (iii) ensuring that only citizens can take part, (iv) providing adequate tools to evaluate the generated data and their application, and (v) ensuring that the government acts on the results.

All this work is irrelevant if the citizens do not participate. Therefore, having a citizenry with a high level of political interest is crucial for a successful democratic process, as high citizen participation in political matters is necessary to ensure that their interests are represented. It is for this reason that low turnout rates when voting are concerning, as voting for representatives is a major tool that citizens have to exert control over their government [164]. Elections are significant undertakings, requiring substantial logistical and organizational efforts, as well as significant monetary costs, with many people not really understanding what the resource costs for maintaining free and fair elections are [165]. Electronic voting has been proposed as a solution for these issues by creating a system where the election data are handled digitally, making voting easy and convenient for citizens who can cast their votes through the internet. The expenses would also be considerably lower than there would be a reduced need for polling stations and resources, both human (e.g., poolers or security) and material (e.g., voting booths or material payments). While the initial investment would be significant, in the long run it would be more cost-effective as the system could be continually reused [166–168]. Nevertheless, it is necessary not only adequate technological infrastructures but also that the population be well-educated and able to use the available services and navigate in the digital environment [169], that is, it is required to guarantee digital literacy and surpass the digital divide.

It is also extremely important to ensure that these technologies are not misused by governments or radical and fringe groups for nefarious purposes [170]. The ability of any individual to create an online community should facilitate discourse. However, due to human nature, it often results in the formation of echo chambers where dissenting or opposing ideas are excluded and the community repeatedly echoes the same ideas to one another. Without exposure to opposing views and ideas, communities can become insular and distrustful of others. This is contrary to the democratic ideals of discourse, cooperation, and compromise. This leads directly into the idea of misinformation, where anything that contradicts the perceived reality of these communities is deemed to be false or inaccurate and orchestrated by others trying to push their agenda. Accusing something of being "fake news" can be a tactic employed not only by these online communities but also by individuals and politicians to avoid engaging in debate or to justify their actions. It can also be used to manipulate large portions of the population and influence the outcome of large voting events, as has occurred with, for example, the Brexit referendum [171,172] and the 2016 U.S. presidential elections [173,174]. This type of manipulation would not be possible without social networks, which provide an environment where these "news" can be easily delivered to an audience of millions. Due to the huge amount of private information that users share, knowingly or not, they can be tailored to resonate with as many people as possible. The free flow of information is crucial for a strong and healthy democracy, so the challenge presented is how to maintain and enhance this flow using ICTs while at the same time protecting it from these attacks.

3. Smart Cities' Technologies

3.1. Smart Cities Architectural Design

As smart cities become more common and their implementation becomes a less ad hoc affair, it becomes necessary for a more planned implementation where the design and building of the smart city is coherently planned before implementation begins. In this section, we will discuss existing architectures for smart cities and their advantages and disadvantages.

Therefore, considering all the dimensions presented above, there is a need for adequate smart cities' architectures. There are many types of possible architectures, but a three-layer architecture is a basic and generic architecture that supports several requirements of the

implementation of smart cities, namely (i) the physical objects necessary for the functioning of the city (e.g., streetlights, traffic lights, or bus stops), (ii) the services provided by the smart city (e.g., lighting management, real-time location of buses, or management of irrigation), and (iii) the collection of data, analysis of data, and communication between the physical objects and the city services. As can be seen in Figure 3, at the bottom is the physical layer, which controls the various physical elements of a smart city, while at the top is the services layer, which provides access to all smart city services. Between them, a middle layer manages all collected data, analyzes them, and connects physical objects with their relevant services.

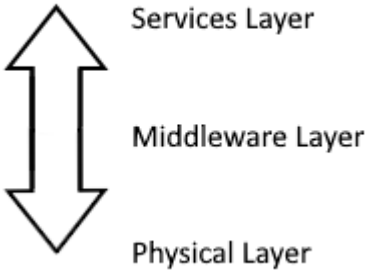

Figure 3. Three-layer architecture.

While this architecture can serve for any implementation scenario, it also lacks the necessary level of detail and nuance required for the specific requirements that a city may need. Additionally, it does not address important considerations, such as security and privacy or system connectivity, which necessitate the use of more advanced architectures.

More advanced architectures, therefore, must guarantee that these considerations are an integral part of the architecture. Security is one of the most important factors to consider, with data having to be properly secured both in storage and during communications, having to address all the myriad devices, the human element, privacy issues, and having a plan to guarantee continuous updating and future proofing. Furthermore, since cities are such big and valuable targets, special attention must be taken against cyber-attacks, and to secure physical infrastructure from attacks [175]. System connectivity is also of paramount importance to a smart city due to how its components require communicating with each other, so it is necessary to guarantee that all devices and systems have access to an adequate communication infrastructure to enable them to perform their work effectively and efficiently [176]. Citizens also require access to this infrastructure so that they may make use of the services provided [177]. Additionally, a common communication protocol must be defined by the architecture, or if such is not possible, it must provide for a middleware to allow seamless communication [178]. It must also consider how data are handled. Smart cities collect and make use of huge volumes of data; therefore, architecture must handle how that data are stored, collated, and analyzed, taking into special consideration what types of data formats to use and their interoperability [179]. Finally, smart cities' architectures must define options for if and how data are shared both within the system and with outside entities, or risk a fractured data ecosystem [180]. This is a subject where open data and open source policies are very significant [181].

One such architecture is the European Union-backed Internet of Things Architecture (IoT-A), which aims to create a reference model enabling true IoT applications. One of the problems for implementations that make use of IoT is that they are often conceived as a single solution to a single problem and thus do not consider communication with other systems. If it is necessary or beneficial to connect with another system, there is no guarantee that their communication protocols will be compatible. The aim of IoT-A is to transform these "Intranet of Things" implementations into true Internet of Things interconnected systems. This would enable different systems to connect seamlessly and to organically grow a smart city technological environment from various projects of various sizes and complexities, instead of needing to create it in a single instance. The IoT-A, completed

in 2013, would thus enable the gradual implementation of a smart city in any location as required [182].

The FIWARE framework is another project supported by the European Commission that aims to provide a platform that allows faster implementation and deployment of smart applications for various problems [183]. FIWARE is open-source and offers a marketplace of components that can be assembled with other third-party components, as well as data models to harmonize data input and output. This enables developers to accelerate development and deployment by allowing them to focus on the specifics of their solution and to use FIWARE components to support security, communications, or data analysis mechanisms [184]. Originally developed for research purposes, the platform is now available for businesses.

While FIWARE is not without flaws (e.g., speed bottlenecks, scalability, or unavailable interfaces), one of its advantages is that new tools can be implemented and deployed to overcome those flaws [185,186]. Examples of these tools are the results of the oneM2M project, a partnership between several countries that developed and promoted the oneM2M standard [187], a standard for interoperability for machine-to-machine (M2M) communications and IoT [188], whose reference implementation, the OpenMTC, optimizes the implementation of IoT applications. Moreover, OpenMTC is but one of the available alternatives. ACME, Eclipse OM2M, OCEAN Mobius, IoTDM, OASIS SI, and ATIS OS-IoT are all open-source implementations of oneM2M that a developer can use [189].

However, research in this area is ongoing since academia and industry continue to propose new architectures with different scopes, such as, for instance, an architecture for a smart city that is adaptable to the needs of each city [190] or the proof-of-concept implementation of the ISCO project of a framework for smart cities that relies on adaptative services based on smart objects [191]. In turn, there are other architectures that have been implemented in real cities, such as SmartSantander, which serves as a large-scale real environment testbed for not only new technologies in IoT and assesses how citizens make use of these technologies and what is their impact on their lives. SmartSantander is built upon WISEBED, SENSEI, and TELCO 2.0 components adapted to work together [192]. CitySDK was another architecture that was deployed in several cities for pilot testing. The deployment consisted of three application programming interfaces to support participation services, mobility data, and tourism information. The objective was to provide data standardization and open interfaces available anywhere in cities implementing the project [193]. These projects enable smart technologies to be implemented and tested in real-world environments and to serve as springboards for the implementation of fully fledged smart cities.

3.2. Standards/Open Standards

Standards for smart cities define the requirements for the technologies and processes that everyone implementing them must abide by. In this way, a base level of quality is established, and different organizations can work in conjunction more easily. In this section, we will discuss the status of standards for smart cities.

Each city faces its own unique set of challenges and has implemented solutions accordingly. Since many of these issues are common to many cities (e.g., traffic congestion, waste management, or sustainability), it is expected that solutions implemented by a city might be usable by other cities. However, since many of these solutions are often tailored to a particular city, they may not be easily transferable to other cities. This stems from the fact of how young the field of research for smart cities is, resulting in a constant stream of new ideas being created and tested. However, there is currently no consensus on a standard approach, and different cities may have varying priorities, even when addressing the same problem. For example, one city may prioritize solving their energy problem by updating their energy grid while another may focus on improving street lighting. This means that cities implement different applications to solve similar problems.

For smart cities to become commonplace, it is necessary for the underlying technologies to transition from the realm of research to the world of market and industry. This requires the establishment of standards that the industry can apply. Standards enable different companies to construct different parts of a smart city and have those parts seamlessly interconnect without additional effort or expense.

The International Organization for Standardization (ISO), an independent organization responsible for developing and publishing international standards in various technical and non-technical fields, has published numerous standards directly related to smart cities [194].

In addition to ISO, there are other organizations that develop and publish standards which are used internationally, such as the International Electrotechnical Commission (IEC), the Institute of Electrical and Electronic Engineers Standards Association (IEEE SA), or the International Telecommunication Union (ITU). Although the IEC and IEEE are different types of organization—the former being an international standards organization and the latter being a part of the Institute of Electrical and Electronic Engineers (IEEE), a North American professional's association—both deal with standards for electric, electronic, and related technologies. The ITU is the specialized agency of the United Nations (UN) for ICTs and works to facilitate international connectivity in communications networks, with one of their responsibilities being the developing of technical standards.

As can be seen in Table 2 these organizations have published several standards for smart cities and they can be organized by their area of relevance: (i) organizational refers to standards that focus on establishing requirements, models, frameworks, and practices on how to implement and develop a smart city; (ii) architectures and interoperability refers to standards on how to implement the infrastructure of a smart city and how the various components operate with each other; (iii) data collection addresses how data are collected and treated to be free of errors; (iv) big data details how the large volumes of data produced by smart cities can be stored, analyzed, and visualized in an efficient manner; (v) artificial intelligence standards handle how ML and AI can be used in smart cities; (vi) security standards handle how to address the various security and privacy risks present in smart cities; (vii) metrics provide the tools to assess and quantify implemented smart city initiatives for review on their effectiveness; (viii) specifics present standards that are used in for distinct smart city applications that may not be addressed by other standards or require more specific details. Additionally, it must be noted that there is overlap in standards subjects across different organizations, which enables different perspectives and ideas to be applied to the same subject and users to choose the most suitable for them.

Table 2. Examples of standards for smart cities.

Title of Standard	Subject
ISO 37106 [195]—Sustainable cities and communities—Guidance on establishing smart city operating models for sustainable communities: This standard provides guidance on establishing smart city operating models to promote sustainability in communities. ISO 37101 [196]—Sustainable development in communities—Management system for sustainable development—Requirements with guidance for use: This standard specifies requirements for a management system for sustainable development in communities, providing guidance on implementing sustainable practices. ITU-T Y.4000 [197] series—Smart sustainable cities: This series of standards provides an overview of smart sustainable cities, covering concepts, principles, and frameworks for the planning, development, and implementation of smart city initiatives. ITU-T Y.4051 [198]—Vocabulary for smart cities and communities: This standard defines key terms and concepts related to smart sustainable cities, providing a common vocabulary for stakeholders involved in smart city projects.	Organizational

Table 2. *Cont.*

Title of Standard	Subject
IEEE P2413™ [199]—Standard for an Architectural Framework for the Internet of Things (IoT): This standard provides a framework for IoT systems, including those deployed in smart city environments, to promote interoperability, scalability, and security. ISO 37170 [200]—Smart community infrastructures—Data framework for infrastructure governance based on digital technology in smart cities: This standard provides general concepts and principles for smart community infrastructures, offering guidance on the integration of various technologies and systems in smart city environments. ISO 21823-1 [201]—Internet of things (IoT)—Interoperability for internet of things systems—Framework: These standards address interoperability challenges in IoT environments, which are relevant to the integration of diverse IoT devices and systems deployed in smart cities.	Architectures and Interoperability
ISO 30182 [202]—Smart City Concept Model—Guidance for Establishing a Model for Data Interoperability: This standard provides a framework for defining, organizing, and interconnecting data in smart cities.	Data Collection
ISO 20546 [203]—Information technology—Big data—Overview and vocabulary: This standard addresses the use of big data including definitions, characteristics, and relationships to other emerging technologies.	Big Data
ISO 22989 [204]—Information Technology—Artificial Intelligence—Concepts and Terminology: This standard explores the applications artificial intelligence (AI) enabling its integration in urban environments.	Artificial Intelligence
ISO 22739 [205]—Blockchain and Distributed Ledger Technologies—Vocabulary: This standard defines the concepts the potential applications of blockchain technology, including secure and transparent transactions, identity management, and data integrity assurance.	Security
ISO 37120 [206]—Sustainable development of communities—Indicators for city services and quality of life: This standard specifies a set of indicators for city services and quality of life, providing a common framework for measuring the performance of cities. ISO 37150 [207]—Smart community infrastructures—Review of existing activities relevant to metrics: This technical report reviews existing activities relevant to metrics for smart community infrastructures, providing insights into measurement frameworks. ISO 30145-1 [208]—Information technology—Smart City reference framework: This standard provides guidance on ICT indicators for smart cities, covering aspects such as performance, quality, and effectiveness of ICT services in urban environments. ITU-T Y.4901 [209]—Key performance indicators for smart sustainable cities: This standard specifies key performance indicators (KPIs) for assessing the performance and progress of smart sustainable cities, facilitating monitoring and evaluation of smart city initiatives.	Metrics
ISO 37162 [210]—Smart community infrastructures—Smart transportation for newly developing areas: This standard defines data concepts for smart transportation systems, facilitating interoperability and data exchange between different transportation systems. IEC 61851-1 [211]—Electric vehicle conductive charging system: These standards address interoperability and communication between electric vehicles and charging infrastructure, which are important considerations for smart transportation initiatives in smart cities.	Smart Transport

These organizations publish standards that are used globally. However, many of these standards are only accessible to members due to paywalls, and being that they

are developed by these organizations, only their members can change and update them. This restricts access for companies or individuals who are unwilling or unable to pay. Additionally, the standards may not be updated quickly enough to accommodate changing technologies, attitudes, or environments. It is for these reasons that open standards exist.

Open standards are accessible to everyone and do not require payment. They are often, but not always, under an open license, allowing for anyone to further develop the standard. This openness can lead to faster development and access to more ideas but comes with the trade-off that there is less control, which makes coordination between different contributors and prioritization of ideas more challenging [212]. This can be both good and bad, as new ideas can lead to unexpected innovations that may not be pursued in a more formal environment. However, they can also cause a split between contributors, leading to the creation of separate standards. While competition breeds innovation, standards are meant to create a solution that can be used by everyone, and competing standards bring confusion to the market.

This is particularly important in the case of smart cities, as not having access to a single set of standards creates a situation where each system uses its own technologies and does not allow for easy communication with other systems. In a smart city where countless systems are expected to be connected, this creates situations where, at best, the smart city is bogged down with middleware between systems, or, at worst, the smart city project is stopped before it is fully realized because it becomes too complex and expensive to implement. This also means that solutions implemented in one place cannot be easily reused or adapted elsewhere, or that a user is locked into a particular system, so upgrades are only possible via the system's vendor, or by throwing out the whole system and replacing it with a new one, which may have the same problem [213].

Open standards counter this, as they allow smaller companies to create systems without being locked out by a lack of money to pay for other standards, and those systems cannot be locked out of other companies' systems due to incompatibility. This allows for the creation of an interconnected IoT environment that is easy to upgrade and expand, very scalable, and cheaper than the alternative. It is important to note that even if an open standard is not completely open—certain parts are locked out, or only a select few can work on its development—if it allows open communication between systems and accessible data, then any system can be connected to another with minimal effort.

3.3. The Power of "Open Data"

Data are the lifeblood of a smart city, and their free flow is essential for a smart city's goals. In this section we will discuss open data and why a smart city having open data sources is an asset and the challenges and opportunities of open data.

However, what is open data? A widely accepted definition is the one from Open Definition: "Open data and content can be freely used, modified, and shared by anyone for any purpose" [214]. The full open definition [215] provides a detailed explanation of the meaning of this summary and the standards that data must meet to be considered open. This definition is crucial as open data are essential for interoperability, enabling disparate entities, which may have never had contact with each other, to access, use, and combine their datasets [216].

It is important to note that open data does not always equate to open access. Data collection can be an expensive process, and the collected data can hold significant value. Therefore, the institution responsible for the collection may want to recoup costs. This can be one of the biggest challenges in implementing open data, with private companies charging high prices for their data, making it inaccessible to those without the resources to pay for it. However, it is possible to pay for data while still keeping it open, and this can actually improve the quality of the data, as long as the cost of the data does not impact the access to it [217]. It is also important to note that many institutions collect data as a necessity for their work, and making it open data and sharing it free of cost is, at worst, a minor burden.

The cities' authorities are significant sources of data, and while some data should not be shared due to privacy and confidentiality concerns (e.g., personal citizen data or confidential information), there is plenty of data that can be made available to the public. Open data has significant benefits for a government, including socially, economically, and efficiency improvements [218]. By making that data freely accessible, it is possible to gain even more benefits, as private entities can create systems that make use of that data to improve the smart city environment in novel or more efficient ways.

Open data are also available from various sources, including scientific, public authorities, non-governmental organizations (NGO), non-profit organizations (NPO), and social media. Often, these raw data need preparation before distribution. This involves sanitizing the data to remove personal information, duplicates, and errors, as well as conforming to open standards. Afterwards, the final dataset should then be made accessible to the public.

Distributing datasets can be a challenging task, particularly for non-influential organizations. It is crucial to advertise the datasets effectively to ensure maximum exposure. With the vast amount of data available on the Internet today, datasets can easily become lost in the noise. As such, efforts have been made to create repositories that allow for datasets to be collected in one place, grouped by relevance, and be easily searchable. These repositories are certified, ensuring that the data contained within is trustworthy. Some well-known repositories include FAIRSharing, the Registry of Research Data Repositories (Re3Data), Zenodo, and Network Data Exchange (NDEx), but more are available for different types of data [219].

3.4. Internet of Things

The importance of IoT for smart cities cannot be overstated, as without it, the current models of smart cities would be impossible. IoT refers to autonomous devices with sensing capabilities, some level of computational power, and the ability to transmit data over a network, which is not required to be the Internet [220,221]. IoT is used in myriad of independent applications (e.g., healthcare, industrial, or environmental applications) [222], but smart city applications are, currently, the biggest domain in terms of scale and number of devices used. In this section, we will discuss how IoT is used in smart cities.

IoT allows for the collection of data and the automation of processes in the different dimensions of a smart city. For example, IoT might be used to improve how energy is generated and distributed since smart meters are able to collect data to be used for the creation of power load forecasts, consumer profiles, or the detection of faults [223]. Still, in terms of energy, smart grids allow for traditional power generation methods, microgrids and distributed power generation to work in conjunction to allocate power as needed [224]. IoT also allows the active monitoring of faults in city infrastructures [225], the maintenance of public facilities (e.g., continuously monitoring the conditions of green spaces such as temperature and humidity [226] and providing smart irrigation to efficiently use water resources [227]), or improving the construction processes in various ways (e.g., worker safety, planning, or logistics) [228]. IoT also impacts mobility by improving transportation in urban and rural areas [229,230] and how aviation companies handle air traffic management or potential issues [231]. Additionally, IoT might optimize healthcare provision [232–235] and facilitate the proactive participation of the citizens in the city government [236].

However, IoT also brings with it challenges; the data collected need to be stored and analyzed, and the tools normally used for these tasks are not designed for the volume generated. Furthermore, new security and privacy challenges have arisen, and new solutions must be designed. Additionally, more dynamic and adaptable systems are required for control and automation as systems become more complex, necessitating the use of AI systems. These challenges are magnified by the scale of smart cities; therefore, more advanced solutions are needed.

3.5. Big Data

Smart cities are predicated on data to function effectively, and their network of devices provides that data in large quantities. However, these data bring their own issues. Firstly, data comes in raw and unformatted, and necessitates preparation and collation to become structured data, which can be then used for analysis and information extraction. Secondly, the large volume of data is overwhelming for standard database and data processing systems, with even simple operations like read or write becoming inefficient and time-consuming. The field of big data was created to handle these challenges, and in this section, we will discuss how the field of big data has evolved to handle them.

Big data can be defined as "data that contains greater variety, arriving in increasing volumes and with more velocity" [237]. However, this definition is relative and what was considered big data in previous decades requiring specialized equipment and techniques to be analyzed and processed can be easily managed with consumer-grade computing today. Therefore, another big data definition states that "data whose size forces us to look beyond the tried-and-true methods that are prevalent at that time." [25].

Parallel computing is an obvious solution to process big data, since when more data must be stored and analyzed, it is possible to increase the number of computing resources. Until recently, this would have required a significant investment in computing resources. However, the advent of cloud computing allows the availability of these resources at significantly lower costs. Cloud computing is also a very scalable solution, with available resources being provisioned and used as needed [238].

Another option available is edge computing, where instead of data being processed in a centralized location, the bulk of the processing happens at the edge of the network of connected devices. In a smart city, this would mean that the devices collecting data (e.g., dedicated sensors or smartphones) would also possess enhanced computing capabilities to send processed data instead of raw data to central storage. This would significantly reduce the work needed from central computer resources, allowing the use of the available resources on other tasks. Edge computing is scalable, as each new device handles its own processing needs and allows for better real-time response and closer interactions with users [239,240].

These options satisfy the hardware requirements for big data computing, but what about the software? New data mining algorithms must be used to take advantage of the parallel processing capabilities of the hardware to extract information quickly and efficiently from large datasets. For this purpose, ML and AI are invaluable, as they can be employed to analyze different types of data and extract useful information from them, while traditional data mining algorithms are designed to be used for a specific purpose on specific types of datasets. Therefore, ML and AI can be used broadly and achieve results with almost any dataset, while specific algorithms are better and more efficient but on a much narrower scale [241]. Nevertheless, both approaches require that the data being processed should be prepared and free of errors. The better the datasets quality, the better the information that can be extracted from them. As such, data must present several attributes (e.g., accuracy, relevancy, interpretability, or accessibility) to guarantee their quality. Big data have their own traits, commonly known as the three Vs (i.e., volume, velocity, and variety), although more have been added over the years (e.g., value, veracity, or viability). These traits have a significant impact on data quality [242], but quality assessment tools for big data are not as mature as those for more standard data. However, new frameworks are being created, such as the declarative frameworks that would allow non-expert users to perform the data quality assessment [243] or context-aware frameworks that aim to allow the systems to know the context of the data (e.g., provenience or metadata) [244].

Being the quality of the data assured, it is also needed to perform data aggregation, that is, several disparate sources need to be combined into one source so that it can be processed and summarized. However, due to the distributed nature of data collection in smart cities, aggregating these data can be time- and resource-consuming. Therefore, several solutions to overcome these challenges have been proposed. One is to create

dynamic routing algorithms that minimize data traffic and congestion by choosing the least congested paths and times [245]. Another is to aggregate the data at various points, namely the sensors themselves, the base station nodes that collect the data from various sensors, or the central servers themselves, and to route the resulting aggregations according to their priority level [246]. A third solution is to correlate and compress the data from a cluster of nodes before sending them to the central server. This allows for reduced traffic and energy consumption with the risk of some data loss [247].

3.6. Machine Learning and Artificial Intelligence

Smart cities are by their very nature immense projects, with many parts working in concert. This would be an unsurmountable challenge without automation. Most components of a smart city are automatic, performing their tasks without human intervention. In this respect, ML and AI allow for automation of tasks with a level of adaptability that was previously impractical. ML uses data to recognize patterns and simulate human learning to improve themselves and be able to perform their tasks more accurately [248–251], while AI enables computing systems to simulate human intelligence and problem-solving capabilities. In this section, we will discuss how ML and AI are used to improve the operations of smart cities, but also the new challenges that using them presents.

ML and AI can be used in smart cities in various types of tasks, from optimizing the sensors energy harvesting capabilities [252] or predicting equipment failure [253], to analyzing data to help in decision-making in (i) urban planning [254], (ii) energy or water usage [255,256], or (iii) traffic management [257]. For example, Google is making use of DeepMind machine learning to reduce the amount of energy used for cooling by up to forty percent [258].

ML and AI might improve the safety of the cities' inhabitants by reducing response times. They can be used to continuously monitor of health conditions [259–261], recognize and provide assistance when needed [262], and approaches that use neural networks are able to quickly and accurately detect instances of fire [263] or to detect traffic accidents [264]. ML and AI can also be applied to predict emergencies instead of just reacting to them, such as a system for predicting fires [265] or traffic risks [266] across cities, or to handle all phases of natural disasters [267]. Shotspotter is a gunfire detection system used by the city of San Francisco, which has helped to reduce the homicide rate to an all-time low. Another system is Avista, a smart video surveillance system that has helped to reduce the crime rate in Minnesota by almost seventy-five percent [268].

Better transportation systems improve citizens' quality of life and access to services. Prediction models can be used to analyze traffic conditions and predict areas where congestion will occur [269], and then used to change traffic lights to adjust traffic and prevent congestion [270]. Additionally, it is of great importance in autonomous vehicles, where it is required intelligent algorithms to correctly act upon the multitude of data provided by a vehicle's sensors to guarantee the safety of passengers and pedestrians [271,272]. For example, the city of Phoenix is making use of AI for traffic management, which has reduced delay times by forty percent [273].

ML and AI techniques might also be used to create digital twins, which are digital simulacrums of a real-world objects (e.g., persons, devices, or systems) connected in real time to their physical counterparts to enable data analysis, remote monitoring, behavior modeling, and the testing of possible upgrades. Therefore, digital twins enable an easier and more cost-effective engineering process and facilitate modelling and testing of very complex systems, such as cities, which otherwise would be infeasible or even impossible. One example is Virtual Singapore, which is the first digital twin of a country. Due to Singapore's limited land space, the government decided that a highly detailed simulation would be of help for land development and to identify flood risks. It can also be used by other stakeholders to make plans in a low-risk environment [274]. However, it should be noted that even with the most accurate modeling of the physical twin and the best data sources, a digital twin is still only a simulation with inherent limitations [275,276].

Environmental protection is one of the most important challenges currently facing humanity; thus, it makes sense to use all available tools at ones disposal to tackle it. ML and AI can be used to more efficiently handle waste management and treatment [277], track pollution levels or serve as early warning systems [278], aid in preparing for extreme weather phenomena caused by climate change [279], and fight climate change directly through helping research, weather prediction, and carbon emissions reductions [280]. As an example, the project I4C—Intelligence for Cities, which uses AI models to predict thermal stress in the city of Freiburg down to the level of individual streets, can be used to automatically determine the best places to plant trees to achieve maximum reduction of thermal stress [281].

However, it must be noted that ML and AI also present new challenges that must be addressed. Security is important, as there are several ways to attack these algorithms (e.g., data poisoning, trojan attacks, or model stealing), which can make them not work entirely or to make them work erroneously [282]. It is also important to define the ethics of ML and AI in how humans create and use those tools, such as, for example, their impact on jobs or individuals' privacy [283,284]. Furthermore, the black box problem exists, where the ML and AI algorithms make decisions, but there is uncertainty as to how they operate and reach their decisions. This has implications for what ML and AI algorithms can be introduced since their decisions are trustworthy, which requires new tools to adequately evaluate these algorithms [285].

3.7. Security

As stated before, data assume a great importance for smart cities since they generate enormous volumes of data during their operation. These data contain sensitive and personal information that must not fall into the hands of malicious actors. Therefore, robust security measures are required to guarantee the data security and privacy. In this section, we will discuss the security risks in a smart city environment as well as what measures can be taken to prevent them and maximize security.

The first place to start is not technological but legal. A solid body of laws and enforcement mechanisms on how data can be collected, accessed, shared, and used ensures that developers must add security and privacy measures to their solutions to be used in commercial environments. This is challenging due to how technological evolution outpaces legal analysis and decision-making. Furthermore, the different laws of different countries are also an obstacle, as an application that is legal in one country can be illegal to use in others [286]. Nevertheless, progress has been made, and initiatives such as the European Union (EU) General Data Protection Regulation (GDPR), despite only being enforceable on EU member countries, incentivize developers across the world to comply with it, ref. [287], as well serve as a foundation for future law changes and as a template for legislation in other countries [288,289].

To guarantee the GDPR, it is necessary to consider the possible risks and measures to minimize them. Starting with data collection, it is necessary to guarantee that any data collected has any identifying information obfuscated or erased to protect the privacy and safety of the person whose data was collected. This is especially important on data collected from social networks, as users share a lot of personal information (e.g., location or names) that might be used by malicious agents to attack the individual (e.g., identity theft, inference attacks, or cyber-bullying) [290].

The next point is data transmission, since all data collected must be transmitted to a centralized location for analysis and storage, which leaves the data in transit vulnerable to various types of attacks (e.g., man-in-the-middle or spoofing). While there are ways to detect if these types of attacks are occurring, the best way to prevent them from being successful is to guarantee that all data transmitted is encrypted [291]. Systems like public key cryptography allow for both authentication of nodes as well as the ability for those nodes to encrypt their data [292,293]. Although these systems are robust, they may be too resource intensive for the IoT systems used in smart cities, which opens the way

to architectures like SafeCity that allow for the encryption of data in resource-strapped systems [294].

Finally, the data must be secured while it is in storage and, therefore, measures should be implemented to prevent access from unauthorized sources and identify attacks [295]. Moreover, encrypting the stored data means that these data must be decrypted before being used, which can only be performed by authorized users. Data encryption is a key measure in countering data breaches, so that even if the security measures of the storage systems fail, the data stolen will be valueless as the breach perpetrators cannot access them [296]. In turn, robust logging and auditorial systems also help to prevent authorized users abusing data for which they do have permission access. Finally, the use of blockchain technology enables the secure and redundant storage of data while creating a security system that is very hard to tamper with and distribute, along with integrated auditing systems [297].

4. Ranking Smart Cities

Smart cities are increasingly being created worldwide as governments incorporate smart technologies into their action plans to address urban issues. Therefore, it has become essential to have a way to measure a city's smartness to evaluate its performance, guide future development, and serve as a metric of a country's advancement on the global stage. Due to the lack of consensus on the definition of a smart city, various methods of measuring a city's smartness exist. Although these methods may be slightly incompatible with each other, they are not necessarily incorrect. They simply measure the aspects that the ranking creator deemed most relevant, and by analyzing the different ranking systems, it may be possible to establish a unified and standard ranking system.

The diversity of definitions of what constitutes a smart city stems from both the evolution of the field and from the priorities of the author. As the technology, the practical and theoretical knowledge of smart cities, and what became possible to achieve with them increased, it also increased the scope of the definition of a smart city and the number of dimensions in which to apply them. This rapid development can make it so that previous research can become outdated before it has the opportunity to be implemented. Additionally, implementing a smart city is a complex process, made more difficult by the need to integrate the disparate systems and their infrastructure across all dimensions of a smart city, as well as having to take into account the needs and wants of the various stakeholders and needing to make these advances available to all the population of the city [298]. Conversely, by having many definitions, it is possible to explore diverse approaches, techniques, and technologies in diverse environments.

One of the initial goals of smart technologies was to improve efficiency. Therefore, ranking systems that measure the extent to which the efficiency of a city has improved with the introduction of these technologies provide a clear and direct way of assessing smartness. However, as shown in [299], where researchers analyzed the performance and efficiency of thirty-two Chinese cities as ways to evaluate smart city implementation (SCI), they found that although they can be used somewhat to guide development and provide historical context, there was no correlation between high efficiency and high smartness of a city or vice versa. Measuring efficiency is best applied to assessing the impact of smart technologies in specific objective areas, such as energy [300] or ecology [301], rather than evaluating overall city smartness.

This occurs because the human dimension cannot be ignored, and the impact smart technologies have on aspects such as culture, quality of life, health, or education cannot be measured solely by efficiency. Various methods have been proposed to evaluate the smartness of cities, taking a more comprehensive approach to consider all aspects [302–304]. However, regardless of their source (e.g., academic, governmental, or private companies), no measuring system has been found to be without gaps in their evaluation [305].

Therefore, no standard method of ranking smart cities currently exists. While research continues on this front, it may be wise to consider that a standard method of ranking might not be possible or may be too complex to create and use. Even if one is created,

methods that focus on just one or a few complementary elements of a city's smartness can still be very beneficial. As stakeholders have specific interests to promote (e.g., economy, security, or energy), they need only to rank those factors that affect their interests. Therefore, instead of a single all-encompassing standard ranking, each stakeholder could use a ranking method tailored to their interests, and a global picture of the smart city's status can then be determined by combining the output of each method [306].

5. Discussion

Due to the demanding requirement of smart cities, academia and industry continue to develop and improve a wide range of technological solutions, as was presented in this review. However, in addition to technological developments, other challenges must be duly considered.

One of the main challenges is the lack of consensus on what constitutes a smart city, due to the youth of the field. Different entities have different views and objectives regarding the application of smart technologies to cities. This results in the implementation of local projects, which are often ad hoc and therefore difficult to upgrade, replicate in other locations, and integrate with other local projects. Even if a smart city is developed in a structured manner that addresses these concerns, the absence of agreed-upon standardized technologies, protocols, architectures, and methods means that the implementation in one city may not be suitable for another city due to various factors (e.g., lack of infrastructure, geography, or climate) or may face difficulties in connecting with other cities that have different implementations. This presents significant challenges when implementing smart technologies and their associated benefits in more large-scale projects (e.g., smart national energy grids, environmental controls, or international trade). Middleware platforms are needed to bridge the gap, as demonstrated by the global parking project, which was implemented in the cities of Santander and Busan, which used different standards—FIWARE and oneM2m, respectively—and thus required a mediation framework [307].

Research projects still constitute a significant percentage of smart city implementations. Due to the lack of consensus, research projects may have varying objectives based on the subjective aims of their researchers or immediate needs for a solution. This has unfortunately led to researchers often failing to share their knowledge and not build upon the work of their peers, instead pursuing their own directions and solving the same problems in different ways. Additionally, many research projects fail to transition from the theoretical realm to practical applications [308,309]. This is one reason why there are multiple technical and non-technical standards, and thus collaborative efforts and research are necessary for the growth of the field of smart cities and for real-world implementation to reach its full potential. Currently, no technical standard holds supremacy over another, and many projects do not use them or even acknowledge their existence for use. Those that do use them should avoid locking themselves into one, as it makes integration and sharing of data difficult and future-proofing harder [11].

Another challenge in smart cities is the potential neglect of the human element. While smart cities offer numerous benefits (e.g., economic or efficiency), it is important not to overlook or ignore the needs of the people. To fully access the benefits of smart cities, individuals require a minimum level of education and digital literacy, as well as access to necessary equipment and infrastructure. When planning a smart city, it is necessary to guarantee that the planned infrastructure is equitably distributed and accessible to all members of the population, especially those who are economically disadvantaged. Additionally, educational programs should be included to address the needs of the population. It is important to plan for projects that enhance the quality of life for citizens even if they have no apparent economic benefits (e.g., cultural programs, urban renewal, or public spaces). Additionally, it is crucial to involve the population in decision-making processes and provide opportunities for them to share their ideas and concerns. Furthermore, it is crucial to prioritize the respect of individuals' data security and privacy in any smart city implementation. This is often overlooked in many projects [309], and failure to do so can

result in loss of trust in the governments' ability or willingness to protect citizens' rights. The smart people dimension, therefore, should not be ignored, for it brings many benefits, both tangible and intangible.

Another important factor to consider is cost. Implementing a smart city requires significant investment in terms of both human and financial resources. Despite the potential benefits, many cities may not have the necessary resources or the willingness to undertake a project that may not yield immediate results. This can be seen globally, affecting both developed and developing nations. One possible solution is to establish public–private partnerships (PPP), where a city collaborates with a private company to implement the project. The city benefits from the completed project at a reduced cost, while the company can enjoy various advantages, such as receiving payment upfront, a share of the project's revenue, and data collection. For example, in India, seventy percent of the funding for smart cities comes from public sources, with the remaining thirty having to come from private ones. However, not all projects are able to gather private support, and when that happens, the project flounders and development has to be scaled down or stopped [310]. Furthermore, the United Nations have promoted public–private partnerships as a way to achieve sustainable development, with governments of various nations (e.g., European Union, United States, and China) instituting policy changes to encourage PPPs [311]. However, independent monitoring is crucial to prevent abuses [312]. The implementation of the smart city can also be completed in stages. Rather than undertaking a single, expensive project, a city may opt to implement multiple smaller projects over an extended period [313]. This approach enables a more gradual and less burdensome allocation of resources while gradually upgrading the city and reaping the benefits of each project. Additionally, it allows skeptical citizens or stakeholders to experience the benefits of a smart city, thereby garnering more support for subsequent projects [59].

It is also important to state that there are many methods for ranking smart cities but no universally accepted standard method. This is due to the existence of both objective and subjective factors in city ranking and the fact that different individuals have varying opinions and interests regarding which factors are important. If a consensus cannot be reached, implementing a standard ranking method may prove difficult. However, individual methods have their own benefits and can be used in conjunction with each other to achieve a very close approximation of reality that can be used to guide a smart city's development.

Finally, it should be noted the importance to remain objective and understand that smart cities and their associated technologies are not a panacea. Despite their growing popularity and benefits, smart cities also have disadvantages that must be considered [314]. Even a fully realized smart city will not magically solve all of its problems. For instance, smart cities contribute to the fight against climate change and the mitigation of its effects, but they cannot achieve this goal alone. Other solutions are also necessary [315,316].

6. Conclusions

Since their inception, information technologies have had a significant impact on almost every aspect of our lives. This impact has only increased with time, and the emergence of ICTs and smart cities has made it even more refined and ubiquitous, reaching into previously unexplored areas of our society. These technologies are changing the way we educate ourselves, communicate with our governments, combat climate change and pollution, approach healthcare, create cultural works, restructure urban areas, and more.

However, despite these advancements, the potential of smart cities remains largely untapped. In the future, we may see fully networked cities and citizens, where practically everything is automated, data flows open and freely to improve our lives, and sustainability and environmental concerns are integrated into city designs. However, currently the field is still in its infancy and experiencing growing pains.

There is no widely accepted definition of a smart city since various definitions exist, each differing based on factors such as ideology or the personal objectives of a person or

project, with only a few shared characteristics. This impacts research, as there is minimal sharing and utilization of ideas between researchers, resulting in the repetition of many different paths of research. This makes it challenging for the field to progress and goes against the principles of scientific work. The creation of standards is also hindered, as while competition can be beneficial for development, when everyone uses their own standards and protocols, it becomes challenging for different products and projects to integrate and work together.

The absence of consensus also impacts the sharing of solutions among cities. Although many cities have opted to use ICTs to address common problems, the lack of standardization means that a city cannot simply license a proven successful solution from another city and implement it. Instead, it must invest resources in creating a similar solution from scratch. Additionally, the absence of a widely accepted standard method for ranking smart cities hinders stakeholders in guiding future developments and comparing already implemented solutions with those of other cities.

Data are crucial for the functioning of a smart city, and their handling must be carefully considered. It is essential to ensure that data collected from the people is performed with respect for their privacy and is appropriately secured. This should be a primary concern for all data collection, but it is especially important when the data are open, as they will be freely accessible to anyone. Open data enables the sharing of data in a standardized way, making it possible for smaller organizations to undertake projects that would otherwise be unfeasible due to the cost and time required for data collection.

In conclusion, smart cities and ICTs have great potential, and many governments and organizations are investing in them, and research into the field has been rising. However, the lack of consensus and cooperation between them has hindered the growth of the field. Therefore, more international cooperation is necessary to build upon research and establish common standards. Otherwise, each smart city will be built on different technological bases, making interconnectedness and interoperability extremely difficult.

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