Chapter

Blending Human Ware with Software and Hardware in the Design of Smart Cities

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Abstract

Sustainable innovation entails realizing society-oriented value creation in an environment-friendly manner. A smart city can be viewed as a holistic paradigm that avails of state-of-the-art information and communication technologies (ICTs, in other words) to advance the so-called "Internet of Things." This aids the management of urban processes and improves the quality of life for the citizens. Smart cities are bound to keep getting "smarter" as the ICTs keep developing. While the technological factor represented by the IoT, augmented and virtual reality, artificial intelligence, urban digital twinning, cloud computing, and mobile Internet is a driving factor unarguably, innovation in urban ecology is a vital socio-economic factor that will spur the transformation of urban areas in the world to smart cities. In this chapter, the authors answer the "what," how, and "who," so to say, of the paradigm—smart cities—with real-life examples and a case study. They emphasize the importance of human ware and remind readers that technology—the all-encompassing Internet of Things with its infantry of cameras, sensors, and electronic devices—though powerful, is a humble servant in the service of the inhabitants of a smart city.

Keywords: artificial intelligence, cloud computing, internet of things, smart cities, urban digital technology, urban spaces

1. Introduction to the paradigm: smart cities

Functionally, one may identify residential, industrial, and commercial areas within a city. The city government and the commercial facilities are usually centralized in the so-called "city Centre" or "central business district," while the residential areas (inner city) and industrial complexes are distributed over the surrounding land area [1]. According to the United Nations (2016), by 2030, 60% of the global population will be urbanized [2]. The paradigm "smart city" was conceived in 2008, when IBM created a plan for the Smart Planet project to build new cities that could support a burgeoning human population, while also enhancing the quality of life for their inhabitants. Leading IT corporations jumped on the bandwagon and the concept entrenched itself. Many countries—Singapore, the United Arab Emirates, and South Korea to name but three, have invested a lot in their smart city initiatives. Songdo (South Korea) can be looked upon as the very first turnkey smart city. Cities, in general, are hubs of creativity and innovation, which stand them in good stead to adapt to/counter/minimize/solve problems/challenges related to rapid urbanization, including issues with social cohesion, the demand for natural resources, the effects of climate change, and rising demand for city services such as transportation, health, housing, and social care [3, 4]. The development and integration of ICTs remove obstacles to the exchange of knowledge and information, and restrictions on innovation while encouraging the dissolution of barriers between different social organizations and activities. The transition from the production paradigm to the service paradigm positively impacts the "industrial form," "city-administration form," and the "urban form" in general [5]. The idea of a "smart city"—from a technocratic perspective—is to manage the inanimate assets in the urban setting to serve the animate entities (human inhabitants) by integrating various ICTs (information and communication technologies) and IoT solutions. The assets include local information systems departments, schools, libraries, transportation, hospitals, power plants, water and waste management utilities, law enforcement agencies, and other public services [6–8]. By utilizing urban informatics technology to improve the efficiency of service provision, and cater to the ever-changing demands of the inhabitants, a smart city strives to make living healthier, safer, more prosperous, comfortable, and enriching for its citizens, by gathering data continuously and promptly addressing any

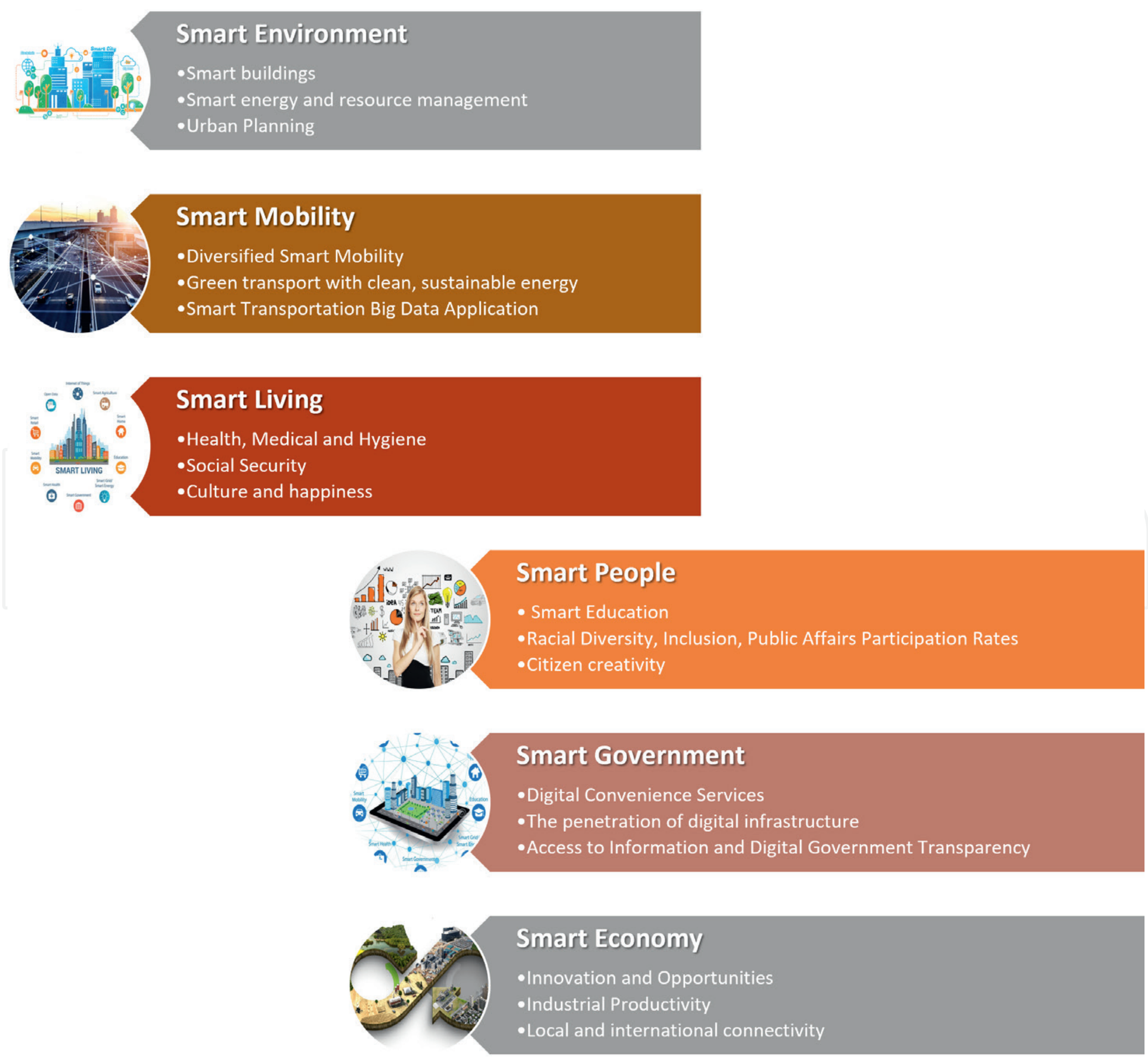

Figure 1.
The six main smart city elements [10, 11].

issues of inefficiency that may crop up [9, 10]. The Center for Regional Science at the Vienna University of Technology has identified six key characteristics of a smart city (encompassing all the pillars of sustainable development), which provides a useful foundation for choosing dimensions while considering a particular city's resources and long-term objectives (refer **Figure 1**) [10, 11].

- Smart environment
- Smart mobility
- Smart living
- Smart people
- Smart government
- Smart economics

Needless to state, to use a metaphor, smart government is akin to the lubricant which keeps the intermeshing gears of environment, mobility, living, people, and economics rotating in tandem. Improvements of [11] and changes in the digital infrastructure [10] are under the purview of "smart government."

What is a smart city?

The "what" if "smart cities" can be comprehended well, by resorting to published literature. What follows is a bulleted list carefully compiled from relevant literature sources.

- The definition of a smart, sustainable city is "an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, the efficiency of urban operation and services, and competitiveness, while also guaranteeing that it meets the needs of current and future generations concerning economic, social, and environmental aspects" [12].

- A "smart" city, or Smart Municipal, on the other hand, is a man-made interconnected system of information and communication technologies with IoT, or the internet of things, which streamlines the administration of internal city activities and improves the quality of life for citizens.

- A city that aspires to become a smart, sustainable city must, in theory, improve its attractiveness, sustainability, and inclusivity, for inhabitants (permanent and temporary) [13, 14].

- According to the Smart City Council, "A smart city incorporates digital technology in all the functions of the

- A city can be defined as "smart" when sustainable economic development with intelligent management with investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure and promote a higher quality of life. Natural resources are used through participatory action and engagement [15].

- A smart city is "the successful integration of physical, digital, and human systems in a built environment to ensure a sustainable, prosperous, and inclusive future for residents," according to the British Standards Institution (BSI) [16].

- There are eight key aspects that define a smart city, according to Frost and Sullivan (2014): smart governance, smart energy, smart building, smart mobility, smart infrastructure, smart technology, smart healthcare, and smart citizens [16].

- A smart city brings together technology, government, and society to enable the following features: a smart city, a smart economy, smart mobility, a smart environment, smart people, smart-living smart governance [17].

- The concept is not static; there is no absolute definition of a smart city, no end point, but a process, or series of steps, by which cities become more "livable," more resilient and, therefore, able to respond more quickly to new challenges [14].

- Smart cities represent a unique specific entity—something that can be taken as a whole and launched as a comprehensive itemized list. All hardware must be linked to the internet of things, all software must be connected, and every component must be instantaneously updated and synchronized for a city to be deemed smart [18].

- This group of cities may be compared to a well-functioning biological creature that promotes social welfare. Digital smart city technologies make life better for inhabitants on all levels. For example, the time wasted in slow-moving traffic is almost eliminated, parking spots for private vehicles can be easily located, and inhabitants feel more secure and safer. In a nutshell, smart technologies will make life more convenient and comfortable, for the urbanites of the world (55% in 2018 and expected to be 60% by 2030) [19, 20].

- The main idea of a smart city is the prevalence of ICTs and the IoT to gather data on energy and water usage, vehicular traffic, air pollution, and other urban "variables" in order to plan, make decisions, change and evolve into a more sustainable urban setting, utilizing resources—be they water, energy, food or for that matter, urban space, optimally [19, 20]. However, authors of Ref. [21] point to the shorter lifetimes of the smart network devices (necessitating frequent replacements) and the high energy consumption associated with the data servers for instance.

2. Wise use of the limited resource: urban space

The need of the century is an agglomeration of urban areas generating sustainable economic development and contributing to social welfare (enhancement of quality of life, in other words), by availing of the six key "smart" characteristics which have been referred to earlier, and thus adapting to or surmounting the sustainability-related challenges of the century [22, 23]. The increase in urban land usage is sometimes referred to as urbanization. The traditional definition of urbanization considers "land-use change" from scattered "exploitation" of the resource to more compact land-use practices [24]. It is an assemblage of architectural and engineering artifices that enable the city's permanent and transient residents to perform their daily functions. Mythologically, the city was looked upon as an analogue of the model of the world—the heavenly world in earthly manifestation, in other words. *"The city is the connection of heaven and earth, and we live in it,"* is one of the many inscriptions on tablets from the Sumerian civilization [25]. The city spaces represent a system that presupposes the presence of material/s (what the studied phenomenon or phenomena consist of/s of). The city spaces can be guided by anthropocentric logic—in other words, place a person at the heart of the urban planning process. The materials in the space will then obviously have the "fingerprints" of the inhabitants, so to say. These "fingerprints" are the needs and values of the human entities of the system [26]. In the past, cities were created to provide safety and defense against outside threats for their inhabitants. Following this, the inhabitants began to group together and become "fellow citizens" to support trade. The purpose of "public spaces" in urban areas is the facilitation of social interaction and communication. These spaces need to express empathy for human needs so that people of any socioeconomic class may feel comfortable when they spend their leisure time there. Using a thermodynamic metaphor, high-quality and lively public spaces provide both sensible and latent benefits to the populace [27, 28]. They serve as incubators for urban development and must be designed/created in keeping with the aspirations of its "users." Practice shows that the most popular urban spaces are multifunctional, providing visitors with options for several leisure activities, and by doing so, attracting people from different walks of life. In today's globalized human society characterized by fluidity and diversity, the approach to urban spatial and structural organization has changed considerably and is oriented toward unification, optimization, and digitalization [29]. Society needs new views and strategies in the context of urban evolution to understand and corroborate the requisites for a "human-friendly, safe and comfortable urban environment," and the modus operandi to get there [30, 31]. Many researchers are actively considering the future of cities in terms of the digitalization of society and the introduction of IT technologies, believing that these processes can influence the creation of comfortable and conducive social conditions. In the process, less attention is paid to the interactions among the denizens of the city. Its significance in the formation and development of individual identities is overlooked. The influence of the environment—both natural and anthropogenic—on society (the society-environment nexus, in other words) cannot be ignored or denied. Cities are centers of intellectual activity, commerce, culture, science, productive labor, social development, and much more [32]. Nevertheless, they are also plagued by a host of challenges, triggered by population growth—overcrowding, lack of housing, lack of funds to provide basic services to the population, and degradation of infrastructure [33]. If these challenges are not addressed pronto and tackled head-on, there is a clear risk of rising discontent, escalating political and racial conflicts, and a spike in the crime rate [34]. What lies ahead for urban planners and city administrators is a gargantuan task Clever, out-of-the-box approaches may ease the way forward a little—utilization of the resources and ideas of the neighborhood to design areas that seamlessly and naturally blend into the urban fabric. The motivator here should be the fostering of a sense of community, *via* creative uses of urban space—like for instance, converting an ancient town square for new purposes, or by rebuilding a park on a site that houses an abandoned factory.

2.1 Modern cities and the "smart city" model

Many cities have implemented "smart city" (hereafter written without quotation marks) policies. Smart city conceptualizations of cooperation place a strong emphasis on a strong inter-stakeholder rapport, which is indispensable for effective collaboration towards common goals. Apart from inter-stakeholder liaison (involving the government, inhabitants, industries, banks, media, academic institutions, commercial entities, etc.), there is also a need for inter-departmental collaboration at the governmental level [35]. "Smart" entails "transparency" and thereby the availability of data and information across open-access networks to inhabitants of the city. Globally, smart cities seek leaders with foresight, who are effective team players. Over the last decade, the concept of "smart cities" has gained significant popularity in policy and research circles. However, as it evolves, it needs to adopt a more citizen-centric approach, instead of being a slave to technology [23].

2.2 Digital city infrastructure

Digital city infrastructure comprises the fundamental information technologies, organizational structures, and associated services and facilities required for a business or industry to operate in a smart city. A given urban infrastructure may be linked to other cities and countries, forming in the process, what could be labeled as regional, national, or global infrastructures. If specific to the corporate world, one could speak of industrial or corporate digital infrastructures [36]. Such infrastructures are complex systems consisting of many subsystems, networked computers, controllers, sensors, and devices, which amass and crunch data, and transmit processed data, alternately called "information" [37]. The digital infrastructure rides over and thereby monitors the physical infrastructure, which includes roads, bridges, parks and buildings, security and safety systems, HVAC systems, water and sanitation networks, power supply systems, *inter alia*.. Digital infrastructure is critical at facilities where a range of services are offered by a host of service providers [38]. Institutions are progressively compelled to reassess their current capabilities, structures, and cultures to uncover possibilities to incorporate state-of-the-art technologies, in the process of overhauling existing work models [39]. Coordinating the multiple tasks happening concurrently within institutions is indisputably a complex, time-consuming, energy-intensive task. Consider this as an example—simultaneous operation of both heating and air conditioning systems on the premises of a firm. The implementation of a digital (city, corporate, or industrial) infrastructure eliminates the complexity of operating multiple systems simultaneously and results in some cost reduction too in the process. Avoiding redundancy by using one single network for the transmission of video, voice, and data is cost-effective [40]. The digital infrastructure available today needs to evolve to meet the ever-changing needs of urban residents, related to the nine components of the digital/physical infrastructure shown in **Figure 2**.

Future smart cities will need to manage almost in real-time, optimize their resource usage, boost mobility, lower noise, and pollution levels, provide easy access to online services, have smart buildings that draw visitors, improve the safety and security of its citizens, and create new economic opportunities. This will necessitate harnessing ICTs, and monitoring and measuring to be able to manage [41]. While data networks are mandatory, data privacy issues cannot be swept under the carpet [42]. The definition of a smart, sustainable city is "an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, the efficiency of urban operation and services, and competitiveness, while also guaranteeing that it meets the needs of current and future generations concerning economic, social, and environmental aspects" [43]. A "smart" city, or Smart Municipal, on the other hand, is a man-made interconnected system of information and communication technologies with IoT, or the internet of things, which streamlines the administration of internal city activities and improves the quality of life for citizens. A city that aspires to become

Figure 2.
Smart city infrastructure components.

a smart, sustainable city must, in theory, improve its attractiveness, sustainability, and inclusivity, for inhabitants (permanent and temporary) [44, 45]. Real-time monitoring generates data collected from citizens (households) and other items of infrastructure in the city (refer **Figure 3**). These data are stored on computer systems in data centers, which can be a group of buildings housing mobile systems and associated components [46]. The data security issues referred to earlier, are very crucial for these data centers; likewise, the energy consumption by the servers which hold the unimaginably huge volumes of data is also a matter of concern [44], especially in smart cities, which have a substantial portion of their electricity being sourced from fossil-fuel-powered thermal power plants. However, the data centers can be equipped with their own renewable power production units for captive consumption, if possible and feasible.

Our understanding of local city dynamics is evolving thanks to smart cities. To design public policies oriented toward improving the quality of life for the citizens, thorough, holistic planning is necessary. All stakeholders involved, all types of resources demanded, and all items of infrastructure need to be factored in, to harness the synergies, and minimize the tradeoffs/conflicts [47]. Personalized smart cards owned by the inhabitants and used at various "points-of-sale," parking lots, public transportation systems, etc., are vital components of the "smart networks" in smart cities. The use of these smart cards enables the city planners to analyze the behavioral patterns of the inhabitants and utilize this knowledge as the basis for decision-making focused on modifications to, and improvements of the city infrastructures [48]. Smart city programs are being implemented (note that this is of a dynamic nature, and is continuous) at the time of writing, in Amsterdam, Barcelona, Madrid, Stockholm, Chicago, Beijing, Glasgow, Dublin, and various cities in India; and there is thus a gradual proliferation of smart meters, smart grids, smart residences, and smart buildings [49]. **Figure 4** illustrates the four characteristics of smart buildings/residences [49].

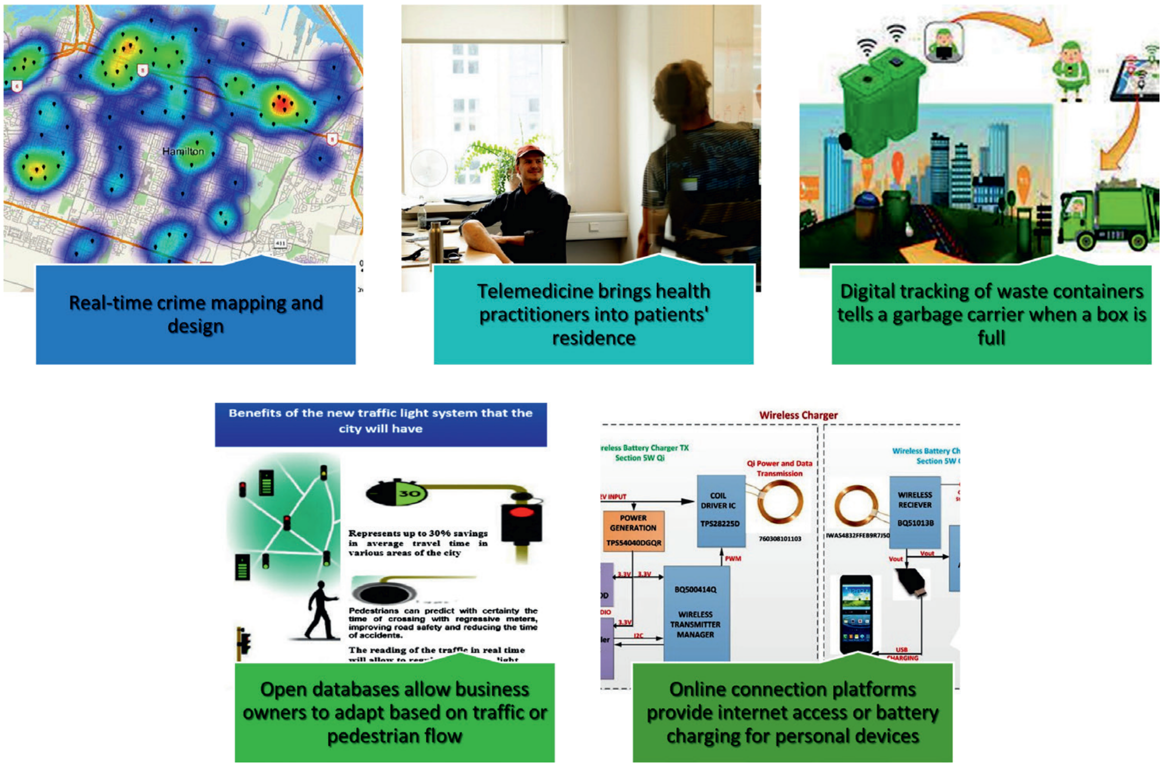

Figure 3.
Practical application in different development areas [46, 47].

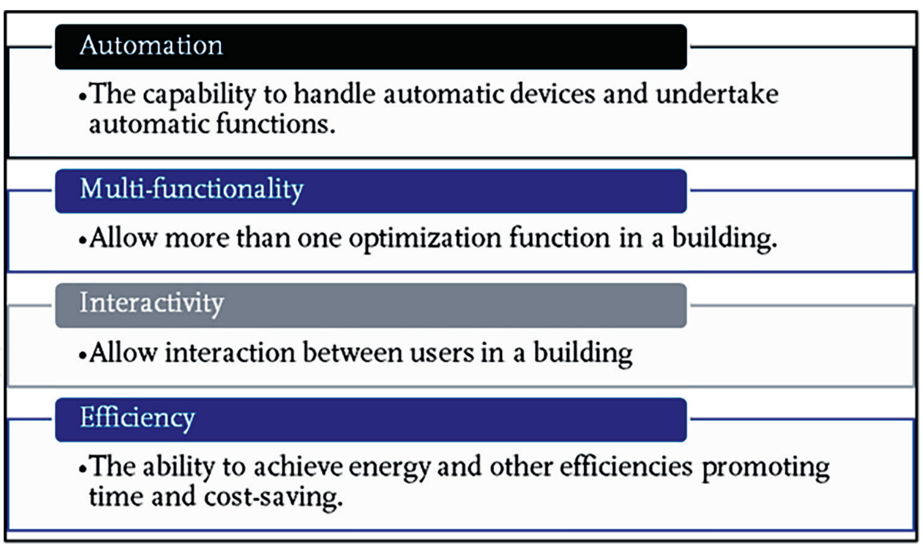

Figure 4.
The four features of smart buildings [49].

3. Smart facility management

3.1 Internet of things (IoT) in smart city

The term "Internet of Things" abbreviated as IoT was coined way back in 1999 by entrepreneur Kevin Ashton, who co-founded Auto-ID Labs (an independent laboratory network and research group in networked radio-frequency identification devices and new sensor technologies) at the Massachusetts Institute of Technology. IoT, which has now come to stay, is often promoted as the next significant advancement in massively dispersed information, allowing any physical device to automatically join online and be searched for by anybody in the world [50]. The Internet revolution has occurred in four different phases—the first three focused on specific devices [51]. Through the IoT (the fourth phase, or wave), these devices that have become part and parcel of the anthroposphere, are all connected to each other directly or indirectly—usually securely—to enable centralized monitoring and control, quick responses to emergency situations, and proactive/reactive strategizing. Indeed, nothing is perfect. There are loopholes and risks and data privacy, as also referred to earlier, is a concern that needs to be addressed with vigil [45]. Intelligent computers which can comprehend, learn, and perform human-like activities and be trained to modify tasks over time to increase accuracy and efficacy are a part of what is termed as artificial intelligence or AI [49]. AI, thus, is a part of the IoT. One application is the control and optimization of the amount of energy used for lighting and heating. Another example is the concept of a "smart factory," in which automated guided vehicles (AGVs) monitor industrial equipment, look for problem areas, and then rearrange themselves to forestall and obviate breakdowns [52].

Traditionally, connectivity relied primarily on Wi-Fi, but today, 5G and other types of networking platforms are becoming more efficient at managing large datasets and providing speed and reliability [53]. The utilization of the data, not the data itself, is the primary goal of data collection. IoT devices gather and send data, which must be very carefully examined to make wise decisions (see **Figure 5**). IoT is slated to grow thanks to developments in AI-supported machine learning and superior analytics [53, 54].

3.2 Artificial intelligence in smart cities

Humankind strives to create better-living conditions in cities, and technological advances have brought about rapid transformations over time [55]. A modern smart city, while developing sustainably, must respect the planetary boundaries and ensure the socio-economic welfare of not just the existing population but also the generations to follow. Decision makers must continuously be aware of the connections, synergies, and trade-offs among these pillars to uphold and advance the principles of this paradigm in the interest of human development and ensure responsible human behavior and actions at the global, national, community, and individual levels [56].

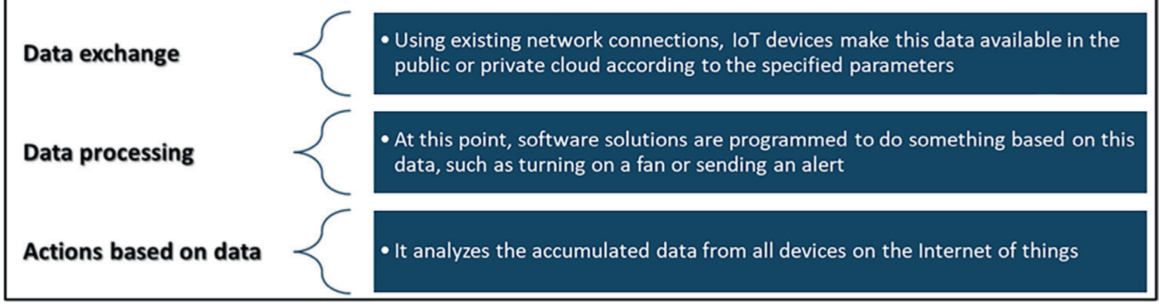

Figure 5.
Smart cities working process.

Artificial intelligence (AI) is a powerful tool in the "toolkit" of urban planners. Smart algorithms are currently helping many organizations in the private and public sectors to improve their operating efficiencies [57]. In the public sector, for instance, city traffic management can be improved significantly by availing of an adaptive AI-based traffic management system [58]. Strategic placement of sensors closes to street lamps/bulbs in public spaces facilitates data gathering. According to a new study, a new breed of intelligent lampposts that can monitor body temperature and recognize crowding may be able to stem the spread of COVID-19 and restore communities [59, 60]. They could also consist of 5G Wi-Fi hotspots, air quality sensors, flood monitors, digital signs, and video surveillance systems. For instance, the municipal council of Barcelona has created a camera-based system mounted on lampposts in the Las Ramblas region to aid crowd management and monitor public health on the beaches [61]. The municipality used scanning devices to get the images and some AI to analyze them to figure out how much of the beach is free. Smart solutions do not have to be universal, perfect, and extremely expensive. Any small improvement using AI, albeit far from perfect, can bring in a lot of value. Organizations must comprehend the value AI technologies can bring to their operations. However, current AI research is more concerned with understanding how AI is adopted technologically than finding its use-related organizational issues [62]. China, for instance, has seen tremendous economic expansion and hyper-rapid urbanization over the last three decades, aided by ICTs, cloud computing, and the IoT [63]. Alibaba's ET City Brain 2.0 is an AI-based traffic management system first adopted by the Hangzhou city administration to report violations of traffic rules in real-time and provide unhindered passage for emergency vehicles such as fire engines, in the event of emergencies [64, 65]. It goes without saying that machines, unlike humans, do not get tired while performing repetitive tasks such as checking the identity of passengers at airports. Repetitive manual work is often error-prone owing to the resulting tedium [66, 67].

AI has sparked controversies around the world, and many of them have not been resolved. Inhabitants are averse to being monitored and label the presence of video cameras collecting data, as an infringement of their right to privacy. However, responsible city administrations must impress upon people the indispensability of AI-based technologies to support intelligent decision-making to ensure greater safety, security, and comfort [68]. The data gathered by IoT applications are typically unstructured. AI-based models extract relevant data from huge volumes of diverse datasets and facilitate focused learning therefrom [69]. As artificial intelligence has grown and its demand for data has expanded, the number of IoT devices has substantially increased. It is common to undervalue the promise that applications of artificial intelligence offer for "smart cities.". At the time of writing, the taxonomy of smart city indicators is under discussion. Additionally, since the concepts of sustainability and resilience are increasingly understood to be linked to the idea of the smart city, more clarification is needed regarding how various assessment frameworks or indicator sets are aligned with sustainability and resilience dimensions and characteristics [23].

3.3 Augmented and virtual reality (AR/VR) in smart cities

ICTs are not without their challenges; they have spawned cybersecurity concerns. Although augmented reality (AR) and cyber-security technologies have been around for a while, of late, they have experienced exponential growth [70, 71]. Augmented reality will be an integral part of the digital infrastructure of smart cities in the years to come [72].

Virtual reality or VR has come a long way since 1961 when it was first introduced for military applications in the USA. The deployment of AR and VR in urban environments offers several benefits, including easy navigation and a good knowledge of the specifics of urban life. It can increase public participation in urban decision-making and contribute to a collaborative urban design process [73, 74]. A "smart city" does not just imply the accessibility of municipal services online, but also entails a deeper integration of such services and automated systems, facilitating proactive asset management and the wise use of urban space [74] (and customer relationship management, where the inhabitants are the "customers" of the city administration). **Figure 6** illustrates the six areas in which AR and VR can be effectively deployed in smart cities.

It is beneficial to realize that the primary characteristic of an urban environment is the concentration of social activity. Therefore, it is necessary to analyze statistics on the environment, commercial activity, and the use of public spaces by the citizens, in addition to traffic data from streets, electrical networks, and water supplies. The social, economic, and biophysical surroundings have an impact on how people act and interact, and thereby on health and quality of life [75]. Visualization helps city authorities to understand the prevailing situation better and make improvement decisions based on such understanding. All these concepts and elements are presented as layers of the urban geographic information system (GIS). The connection with urban GIS is the most understandable and well-developed use of VR and AR in smart city technologies. At the same time, Web virtual reality (WebVR), IoT, and three-dimensional (3-DGIS) geographical information system (3-DGIS) with peer-to-peer (P2P) networks are some of the most recent integrated IT tools. These are useful while handling spatial "big data" (remote sensing data) [76]. Much has been written about the potential of smart urbanism to bring about varied and permanent types of progress, including favorable energy efficiency improvements and a heightened sense of environment friendliness [77].

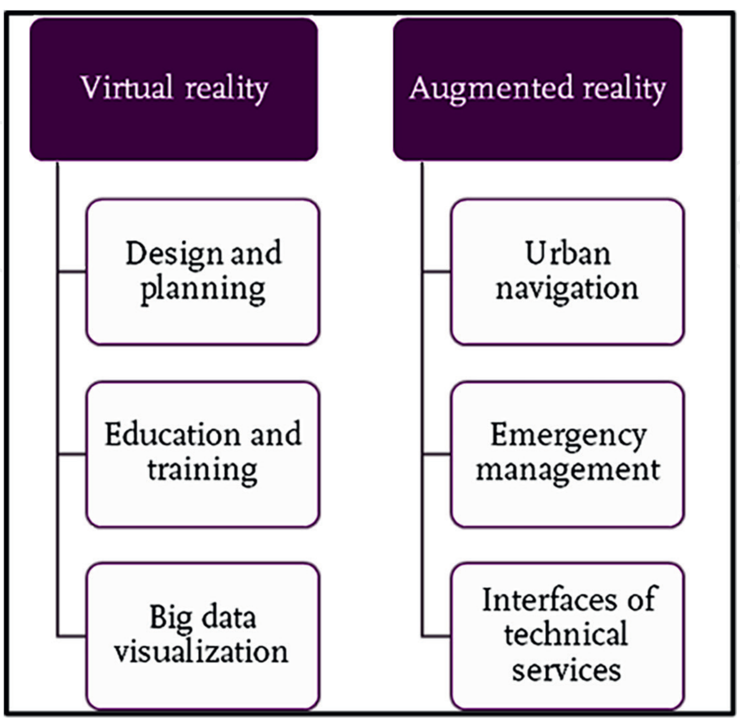

Figure 6.
The six critical areas for the use of virtual reality/augmented reality in a smart city [73, 74].

3.4 The urban digital twin technology

The urban digital twin (UDT) technology combines 3D city models with dynamic data from sensors and GIS technologies, and contributes to a much-better understanding of cities [78]. This strategy is based on the idea of the possibility that a static structure with dynamic features will arise. Although this technique has industrial and technical roots, NASA employed it for the first time in the 1960s to physically duplicate systems on Earth to match those in space. The digital twin is now within reach as production and manufacturing become increasingly digital, and the IoT becomes all-pervading. Digital twins are created to interact with their environment in several ways to replicate complex structures and processes for which it is challenging to predict effects throughout the product's existence.

This link between the actual and virtual worlds occurs almost instantly, and more precise forecasts can be made well in advance to enable adaptation or preventative management [79]. Due to its low cost, rapid analysis, minimal risk, and potential for substantial insight, the simulation of manufacturing systems is a potent tool for the analysis of systems, and an understanding of the roles of and the interactions among the components thereof. A software equivalent of a physical item mimics a real thing's inner workings, technical details, and behavior [80]. The digital twin's use of sensor data from an actual device working in parallel to set input actions on it is a critical component of data-driven decision-making, monitoring of complex systems, product validation and simulation, and object lifecycle management. Both offline and online modes of working are possible. Additionally, information from the digital twin's virtual sensors and the actual device's sensors may be compared to find abnormalities and the causes thereof (**Figure 7**) [82].

Although there has been a proliferation of publications related to UDT (or DT, rather), any investment in such technology needs to be made, after a thorough understanding of the requirements, purposes to be served, and the benefits and limitations of the technology [83]. The academic sector, businesses, and the public transportation

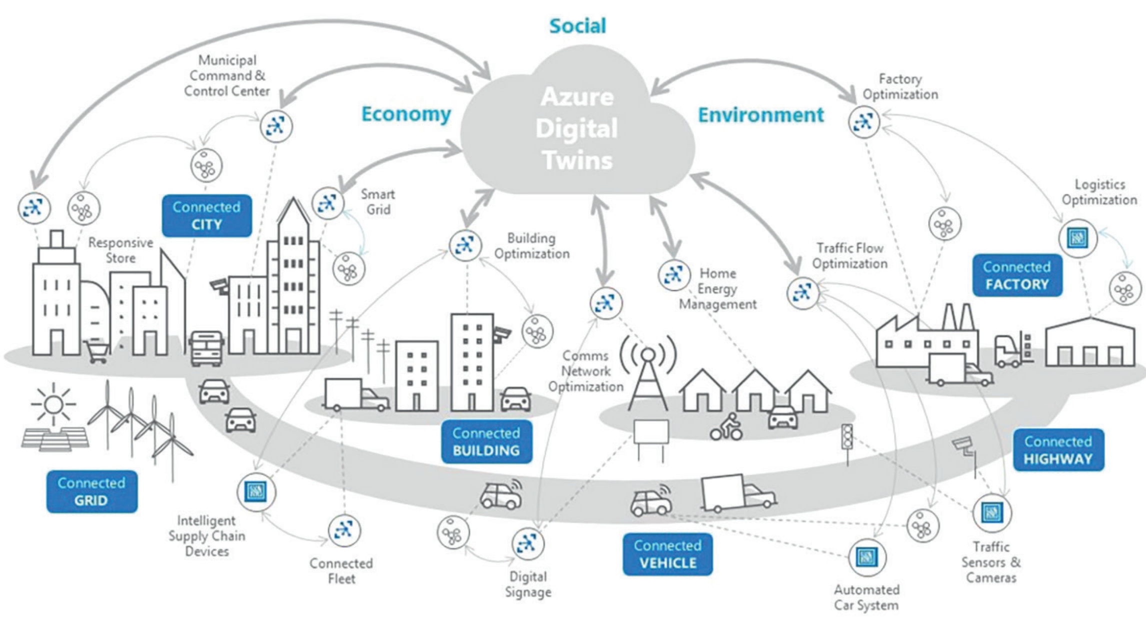

Figure 7.
Digital twins, environments of all types [81].

sector are particularly interested in DT, as it holds promise to help users surmount the challenges posed by tighter profit margins, and stringent quality demands imposed by regulators and consumers, and productivity improvements expected by investors [84]. Creating smart cities is a complicated process involving a web of interactions among municipal departments, external stakeholders, and a wide range of service providers. City planners may create smart, sustainable, safe, and liveable smart cities with the use of two technological practices: urban information modeling (CIM) and city digital twins (UDT) [85].

3.5 Urban drones in smart cities

Drones are vital components in smart city networks, supporting a plethora of functions (see **Figure 8**) ranging from delivery of packages to policing to traffic monitoring to firefighting to rescue operations during natural calamities [88]. However, due to the absence of established algorithms for using urban drones in both standard and special circumstances, it is desirable to assess the drone-related experience and identify the most valuable strategies for future best practices [89]. When traffic and street cameras do not serve the purpose or are absent, drones can step in as replacements. The quadcopter can provide real-time video surveillance and help to avert natural catastrophes, investigate traffic accidents, photograph scenes of crime and gather evidence, and detect faults in infrastructures. The features of urban drones differ based on the platform and the intended application, and thereby a classification must take into consideration a wide range of factors [90]. Most of the drones studied, utilized single-rotor, rotary-wing drones with cameras serving as aerial sensors [91]. Perhaps, using drones to deliver packages can reduce traffic congestion (as drones would be replacing road vehicles which would otherwise be deployed for the courier

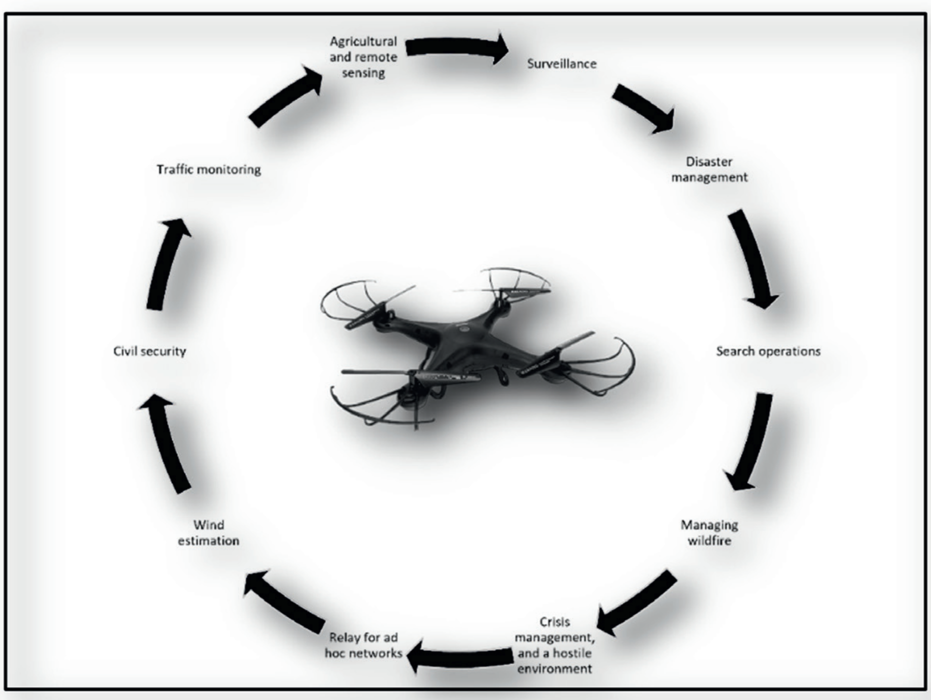

Figure 8.
The role of drones in a smart city [86, 87].

service), curtail air pollution [86], save time [87], and venture into areas that would be a wee bit difficult for rescue workers to directly get to [92]. Cumulatively, over time, the benefits would be conspicuous.

4. Application of the IoT

4.1 Cloud computing and peripheral computing

Applications connected to the IoT have become interesting areas of research for engineers and academics. This testifies to the size and significance of data-related issues that must be resolved in modern commercial enterprises, particularly in cloud computing. Just like network connections, the expansion of cloud computing is strongly tied to the growth of the IoT. Due to its ability to provide processing power and on-demand storage for big data, IoT cloud services have allowed devices to capture, store, and transmit larger and more complex sets of data [93, 94]. Additionally, while retaining the security of a closed system, private cloud solutions have allowed businesses to handle significant volumes of different types of IoT data. Traditional urban management techniques and technologies can no longer keep up with cities' demands and diversified development needs—road traffic management, medical and health services, and public service facilities [94]. Just as network connections have been closely tied to the growth of the IoT, cloud computing too is. Because IoT cloud services can provide processing power and on-demand storage for big data, applications can be hosted in the cloud. A cloud computing service provider makes public cloud services available, allowing third parties to update the IoT environment and incorporate data into IoT-enabled electrical products [95]. Urban architectural standards have evolved over time and are often in a state of flux, which is due to the rapid alteration in the influential factors [96–98]. The sustainable development goals (SDGs) of the 2030 Agenda for Sustainable Development of the United Nations include, among other things, making cities more sustainable and resilient. ICT solutions relevant to different urban systems and domains come into play here [99]. Most urban stakeholders (service providers as well as service receivers) see cloud computing as an emerging and attractive strategy for healthcare. It has the unique capability to provide limitless capacity and power of procedure in e-healthcare [100]. For example, the IoT will optimize the provision of urban medical services, and this will improve both intra-sectoral and inter-sectoral communications. Patient data are valuable assets that need to be stored and referred to, also in the future. Cloud computing will serve to reduce the human labor required for the storage, retrieval, and interpretation of these records. Cloud computing may also be utilized to construct databases and platforms for medical and health services. Additionally, patients may register remotely through the IoT, and this healthcare access can be provided to 100% of the urban population quite easily [101, 102]. Cloud computing can perform real-time forecasting and evaluation of traffic conditions, analyze traffic development trends, offer trustworthy decision-making resources for traffic management departments, and facilitate road traffic guidance. Based on the current remote monitoring system of traffic, the traffic signal lights are managed and controlled to achieve adequate traffic flow control, and almost eliminate the likelihood of an accident. The standardization and unification of road traffic management may also be achieved by remote traffic control and electronic toll collection, eliminating the problem of slack law enforcement brought on by "human-friendly" management and promoting society's peaceful and steady growth [102]. IoT devices are often widely dispersed across different regions, but they all transmit data to a single central system [109]. As IoT data volumes increase, a corporation may run out of bandwidth and cloud capacity. Additionally, gathering, transmitting, processing, and receiving data at its destination become more time consuming. Furthermore, inefficiencies result from this "delay" especially in businesses where real-time information is crucial for success in the marketplace. With the help of edge computing technologies, the processing can be decentralized and moved closer to the data source [103], by effectively deploying localized computing systems and boosting the processing capability of the IoT devices in the process.

- The sensor-based smart city of the future will be composed of four technological layers [104]. Sensors, which can be automated terminals, wireless and mobile sensors, and network cameras recording images, videos, and sound.

- All these sensors on the city network, connected through the communication infrastructure

- Data collected by the sensors are consolidated, processed, and analyzed to obtain useful information

Time series analysis is possible to understand the trends and patterns, related to energy usage, noise reduction, traffic optimization, and implementation of safety and security measures [105].

4.2 Smart surveillance

Urban lighting systems can double up as surveillance systems in a smart grid [106]. Installing street lighting surveillance technology does not require creating a complete smart grid. In numerous UK cities, a microphone system is installed on streetlights, and the possibility of adding cameras to them is being discussed, at the time of writing. People who live in regions that are vulnerable to crime and terrorism have experienced several changes in their daily routines, which have affected the quality of their lives [107]. Microphones installed on lighting systems to detect angry and suspicious voices, activate cameras connected to the, investigate the sources of the voices further—this is in vogue in New York City for example. As the populations in cities keep increasing, so does the crime rate, as the potential returns for criminal activities are obviously larger in bigger, densely populated cities with more wealthy inhabitants [108, 109]. The standards for installing and employing video surveillance are not usually explicitly and comprehensively defined in legal terms, and this absence of standardization leads to cities in different countries adopting different approaches to avail of this technology to fight crime [110]. Regardless of the weather, intelligent technology can "recognize" faces up to 70 meters [111, 112]. Real-time analysis enables one to react immediately to emergencies.

5. Illustrating with a case

5.1 Smart city model

Expectations of urban inhabitants have changed radically, owing to the realization that ICTs are indeed able to provide them with better services than before. This necessitates better space planning (as urban space is a limited resource) [113]. The effective use of urban space is of paramount importance if transport-related problems are to be solved in a smart city. There is a critical upper limit to the number of vehicles, which can be plying on the roads (again, fixed lengths and thereby fixed traffic capacity) at a given time, without causing congestion. Parking spaces are always at a premium when the fleet of private vehicles in the smart city increases. Thereby, one finds the clever use of underground spaces [114], or the introduction of multi-storeyed parking facilities.

It goes without saying that in developed cities, the creation of a digital matrix of target indicators is crucial as a management tool for a "smart" system and as a description of the current space-planning structure of the city, both above and below the ground. As a result, soft or non-physical assets share a significant capital component with multiple effects in many situations for a smart city. In addition to the advantages offered by the conventional physical infrastructure, they allow a city to implement and mainstream a people-centered strategy [115]. The combination of typical indicators and opportunities adequate to the spatial resources of the city development provides the basis for identifying the development vectors of the system, and the thresholds for their actual implementation—the so-called certainty thresholds. In year-2013, Vienna, Toronto, Paris, New York, London, Tokyo, Berlin, Copenhagen, Hong Kong, Barcelona, Boston, San Francisco, Amsterdam, Karamay, Singapore, Songdo, and Sao Paulo were rated as smart cities [116–118]. Four years later, in 2017, Copenhagen was named as the most technologically advanced one. Cities such as Singapore, Stockholm, Zurich, Boston, Tokyo, San Francisco, Amsterdam, Geneva, and Melbourne were the other 9 in the top-10 list. The next subsection focuses on Singapore in greater detail.

5.2 Singapore as a smart city

Data generated by billions of individuals daily through their usage of modern technologies and social media had made artificial intelligence possible [119]. Singapore has structured its public and private transportation networks, installed smart traffic lights and sensors to measure traffic congestion, introduced smart parking throughout the city, and will soon see the widespread usage of autonomous cars. Despite being a wealthy country, Singapore is well known for its strict social laws. A few years ago, Singapore started an initiative to transition to a smart city. The "whole of nation" approach was adopted to give better assurance of success and experiment with new technologies and concepts of IoT and CPS (Cyber-Physical Systems). Technology maturity, ease of use, and public acceptance were emphasized. All aspects of urban infrastructure, including transportation, telecommunications, healthcare, and resources management, would be encompassed [120]. To date, the whole world is interested in Singapore's emphasis on environment-friendliness in their urban design approach. Technology has enabled a selective application of robotics to either supplement or replaces tedious human labor [121]. The Smart Nation concept aims to use sensors linked to aggregation boxes to gather citywide data digitally. The competent agencies get the data collected on pedestrian activity or traffic volume for analysis and decision making in the delivery of services. The National Research Foundation oversees enhancing Virtual Singapore, a dynamic 3D city model, and a collaborative data platform for planning. Public and commercial businesses can use it to create tools to evaluate ideas and products, such as modeling crowd dispersals from potential sports arenas [121]. The government wants to install solar panels on the roofs of 6000 buildings by 2022, as well as smart and energy-efficient lighting for all public routes [121]. Singapore is now really "smart," thanks to several strategic programs undertaken by the government in close

Figure 9.
CODEX platform [122].

collaboration with other stakeholders in the country. New technologies are currently being tested in the city. It relates to "life issues" and the electronic government. They develop a CODEX, a digital platform that swiftly and effectively offers citizens digital services (see **Figure 9**) [122, 123]. Through the Moments of Life initiative, parents can register a new-born, find a kindergarten, or find information about necessary vaccinations, older people can find out about public services, and professionals can find a job.

5.3 Smart public transport and unmanned vehicles

Notwithstanding recent developments, resolving traffic congestion problems has not been easy in Singapore [124]. The government is seeking to address this issue by restricting the number of vehicles on the road and raising costs. However, a successful transportation policy may be achieved with innovative ideas:

- Sensors: With their assistance, traffic can be diverted when sectional congestion is identified.

- Autonomous taxis: The cost of transportation will be lower without a driver.

Over time, people have realized the negative impacts (congestion, noise, and air pollution) of unrestrained use of private vehicles—both four wheelers and two wheelers. There is an increasing predilection for the use of public transportation. Out of 5.6 million people, there were 7.54 million daily bus trips nationwide in 2018, and attempts are constantly made to improve the quality of service provided [125]. To test robotic automobiles, the whole western portion of the nation—more than 1000 kilometers of roads—was made available to businesses. Since last year, locals have used autonomous busses and shuttles, and the nation's first unscrewed taxis debuted in 2016 [126]. Standards for drones have been formalized, to increase the effectiveness of developing and introducing new robots on the road.

5.4 Smart multipurpose lighting

Making a city smart requires investments in high-speed fiber networks, smart city technologies, a strategy for data-sharing and data security, and a master plan for urban growth. The adjective "smart" must perforce also imply "sustainable," "equitable," and "inclusive" [127]. The "Lamp Pole as a Platform (LaaP)" trial initiative was launched by Singapore in 2018, and streetlights were integrated with various sensors, including cameras with facial recognition software. Upscaling to track human activity and monitor air quality, will make it multi-functional and multipurpose. The project is a part of the broader Smart Nation program, which aims to use cutting-edge technology for "crowd analytics," to combat terrorism and augment the safety and security of the inhabitants of Singapore (**Figure 10**).

To date, over 100,000 lampposts in Singapore are equipped with surveillance cameras, which might soon assist law enforcement in identifying people in crowds (**Figure 11**).

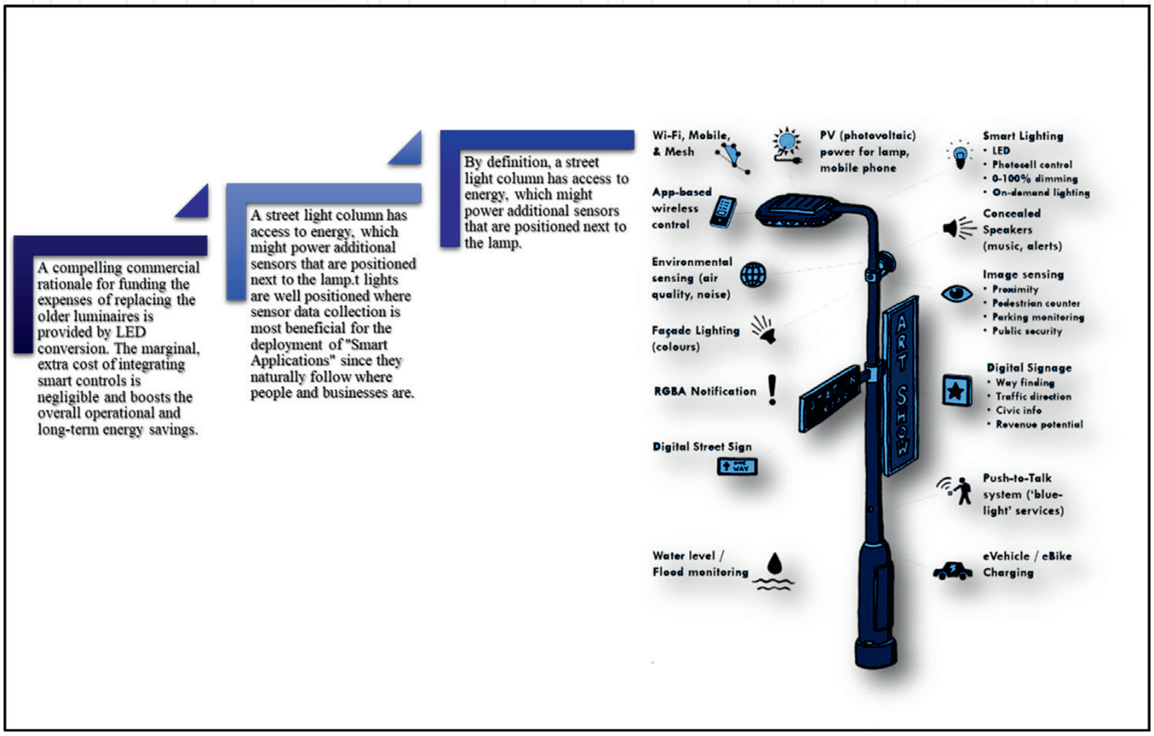

Figure 10.
'Lamp pole as a platform' initiative [128].

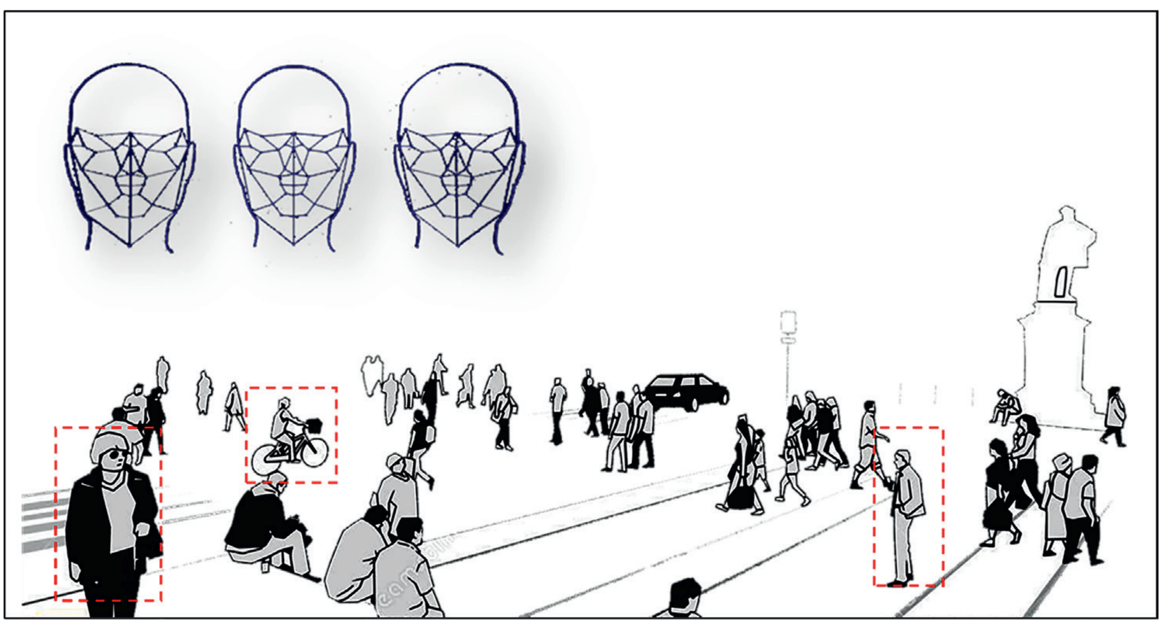

Figure 11.
The technique for identifying faces in crowds.

Such video surveillance can stifle free expression and association, violate the rights to travel and rest, and erode the right to privacy in general [129].

5.5 Education and tech-savviness

In the 1960s, English was mandated as the medium of instruction in schools, and universities started teaching entirely in English. Additionally, the government-sponsored students who intended to study abroad. The bilingualist strategy focusing on speaking English and the native tongues of the three major ethnic groups: Tamil for Indians, Mandarin for the Malay population, and Chinese for the Chinese community, mandates that pupils in schools learn both their respective mother tongues and English [130]. This characterizes a high level of concern and respect for human capital. As part of the Smart Nation Fellowship, specialists from abroad are attracted to Singapore [131]. By analyzing Singapore's recent Smart Nation effort, the authors of this chapter would like to recommend the inclusion of the actual human and embodied work into the 'smart urbanism' paradigm.. Smart Nation Together is an educational course on programming and teaching technologies, including 3D printing and artificial intelligence, designed for children, adults, and the elderly [132].

5.6 Healthy is smart, smart is healthy

A complex housing several research facilities, medical facilities, and entertainment spaces will be constructed in Singapore, by 2030. Health City Novena's master plan aims to create an infrastructure that makes sidewalks, underground parking lots, and parks as comfortable as possible for patients [133]. The developers have made the inanimate infrastructure subservient to the animate entities it is meant to serve—patients, students, guests, and employees of these facilities. Singapore's digital environment makes it possible to both receive and provide services. If someone needs urgent medical assistance, a responder app alerts medical volunteers within a range of a kilometer [134]. Harnessing the benefits of the "enabling aspects of technologies" to the fullest for its citizens, is what has been the hallmark of Singapore's entrenchment as a leading smart city (city-state) in the world [135].

Highly reliable high-speed Internet and the ubiquity of smartphones (some Singaporeans own more than one smartphone) characterize Singapore. This makes it possible to unburden doctors, by organizing remote consultations in cases where the ailment is mild, or the patient query is simply about preventative/prophylactic measures [136].

5.7 Continuous collaborative innovation

Singapore has been a hotbed of innovations, and a crucible for experimentation, for many years now. The government, in its capacity as financier and promoter, works shoulder to shoulder with tech-start-ups and experts in academia and industry, to keep innovating, testing, and implementing briskly.. Singapore's innovation policy while facilitating continuous urban transformation within this city state also has positive spillover effects on other countries in ASEAN, Asia and elsewhere in the world, which can learn from the success of this innovation-powerhouse in South-East Asia [137].

5.8 Digital Singapore enabling resources management

Thousands of cameras and sensors make it possible to create a digital copy of the city. This is necessary to predict various events, from natural disasters to pandemics [138]. In addition, the digital model keeps track of the number of inhabitants, resource consumption, climate change, and many other factors that impact their lives, favorably or otherwise. Resource scarcity (or rather an impending resource scarcity) is directly correlated with the population density of a city. Smart meters and sensors come in handy here, to limit resource consumption in both the residential and commercial sectors. Singapore has incorporated cutting-edge automation technologies—bolstered by ubiquitous sensing and data gathering—to address a host of challenges related to the management of resources [139]. Solar panels are integrated into building facades, to generate electricity for captive use. The NEWater wastewater treatment and recycling system meet 30% of the city's potable-water needs, reducing its dependence on freshwater imports from Malaysia. Modular vertical farms, designed to enable all the plants to have adequate sunlight and water, enable efficient farming, in a country where arable land is at a premium [151.

6. Results and conclusions

A smart city takes recourse to digital technologies to streamline all "urban operations" to enable quality-of-life improvement for its inhabitants. In addition to promoting social well-being, it also has a beneficial impact on industrial development and economic growth. Businesses are impacted favorably by digitization, as it gives them an attractive return on investment. Emergencies necessitating quick remedial measures can be effectively managed if smart technologies are availed of. The IT infrastructure of a smart city is comprised of several networked computers, controllers, sensors, and devices. These subsystems gather huge volumes of data that need to be stored, crunched, and transmitted. The city administration can communicate directly with the inhabitants (as well as with all the urban infrastructure elements) through the IoT. This will enable the administrators to monitor and measure in real-time and combine proactive and reactive approaches to adapt and evolve and keep enhancing the quality of life of the city's inhabitants. Building a smart city calls for comprehensive perception, ubiquitous interconnection, ubiquitous computing, and integrated applications through new-generation IT applications like the IoT and cloud computing, represented by mobile technology.

Wikis, social networks, and complete integration techniques must be used in smart cities from the standpoint of social development to actualize a knowledge society characterized by using creativity and innovation which is free, collaborative, and benefits the masses. For instance, smart (adjustable) street lighting can conserve a lot of energy. Smart traffic lights can autonomously select the mode of operation depending on their analysis of the flow of vehicles and the traffic scenario. All public locations with video cameras and emergency call panels serve to ensure security. Real-time information—about various aspects of the lives of the citizens, like healthcare, utilities, security, and transportation, inter alia—streamed from the cameras is gathered and examined. Smart houses and buildings are also a component of developing smart cities.

Managing urban infrastructure, such as transportation, education, healthcare, housing and community services, security, requires the integration of several ICTs.

The overarching goal of developing a "smart city" is to augment the standard of living of its citizens by employing urban informatics technologies to enhance the effectiveness of the services provided. For a qualitative improvement in the level of security, a move to proactive actions that enable crime prediction and resource allocation planning is required. By examining historical data on antecedents, it is possible to develop risk profiles.

A smart city is an advanced kind of "urban informatization" that completely utilizes the new generation of ICTs in all areas of urban life. Ideas for regional development like e-government, intelligent transportation, and smart grids commonly merge with smart cities. Smart cities must necessarily have other attributes such as "eco-friendly" and "low-carbon."

While technological innovations aided by ICTs are looked upon as solutions for all challenges by some techno-optimists, it must be borne in mind that "smartness" is incomplete without human-networks-building and human capital development. Smart cities, after all, must be "of the people," "by the people," and "for the people," with technology being just a humble servant of the masses.

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