Chapter 1

IoT (Internet of Things), Cloud Computing and the Elementary Building Blocks of Smart Sustainable Cities

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Abstract

As the size of the population is growing and the capacity of the planet Earth is limited, human beings are searching for sustainable and technology-enabled solutions to support society, ecology and economy. One of the solutions has been developing smart sustainable cities. Smart sustainable cities are cities as systems, where their infrastructure, different subsystems and different functional domains are virtually connected to the information and communication technologies (ICT) and internet via sensors and devices and the Internet of Things (IoT), to collect and process real-time Big Data and make efficient, effective and sustainable solutions for a democratic and liveable city for its various stakeholders. This chapter explores the concepts and practices of sustainable smart cities across the globe and explores the use of technologies such as IoT, Blockchain technology and Cloud computing, etc. their challenges and then presents a view on business models for sustainable smart cities.

Keywords: Smart city; sustainable city; information and communication technologies (ICT); Internet of Things (IoT); blockchain technology; cloud computing; business models; city planning

Introduction

The journey of human civilisation from deep forests, hunters to settled tribes with agriculture, to villages and then cities and so on could be used to learn about our current journey towards sustainable smart cities on earth and then maybe in space in the future. This journey explains why the homo-sapiens decided to aggregate themselves into tribes, and then settled in their living spaces with self-employment

Technology and Talent Strategies for Sustainable Smart Cities, 1–33

Published under exclusive licence by Emerald Publishing Limited
doi:10.1108/978-1-83753-022-920231001

as the main means in villages to address their basic physiological, safety and social needs. As the economy and globalisation spread, the means of achieving those personal needs diversified into industrial economies, business and external jobs and external employment. As the population started immigrating and emigrating, some villages gradually added infrastructure and economic activities at their existing location and they became big villages or cities; on the other hand, due to the top-down approach of governments or kings some cities were established from scratch as the centres of social, administration and economic activities. This journey explains what a city is and why people started living in the cities! As the resources became more limited and the size of the population swelled, the cities started thinking about another movement to serve the new needs of many stakeholders. But due to limited land, labour and capital, etc. the idea took the direction of efficient and effective cities that may be smart cities; and recently the idea evolved into sustainable smart cities; and the idea is still expanding into the concept and reality of cities in the outer space and so on. Why these kinds of developments are happening? What are the reasons and the needs? Is it top-down reasons (government, MNC (multinational companies) corporations, city administration) that are pushing the development of smart cities or is it bottom-up reasons, i.e. citizens and other stakeholders want such happy liveable living spaces?

Growth of population implies that cities will occupy around 60% of world's population by 2030 and might reach around 75% by 2050. Frost & Sullivan forecasts a US$1.5T global market opportunity in smart cities' with needs of energy, transportation, healthcare, building, infrastructure and governance. We need to meet the current and future demands of citizens and other stakeholders of any city, and only a smart, intelligent and sustainable city can do it effectively.

What is a smart city? What is a sustainable smart city? Why do we need it? As the size of the population is increasing, multiple issues such as limited capacities of resources and infrastructure of the city, the living standards of the people and the ecological balance of the cities, etc. are being faced by humanity.

A Smart city has many building blocks such as urban space, government, citizens, mobility, energy and a sustainable environment connected with ICT.

In some eastern philosophies, the five elements which are the building blocks of all living beings are space, air, water, fire and earth. So a smart city or a smart nation or a smart location or a smart home is an integrated system of all those five elements. A smart city is all about organising the horizontal and vertical space of the city, so that the consumption and production of its resources, such as environmental quality, water and sewage treatments and energy, are in line with the sustainability of the planet Earth. This requires efficient production of food, disposal of waste, efficient use of land for recreational or festivals or playgrounds and so on. In a smart city, various building blocks or elements will be well-integrated so that the city has the maximum possible capacity, and the city operates democratically, efficiently, effectively, transparently, equitably and sustainably.

Sustainable related activities are the principal areas of interest in the future smart city. Such activities should analyse and balance the needs of *society* (safety, health, access, equity), *ecology* (climate change, air quality, noise, land use, biodiversity, waste) and *economy* (growth, efficiency, employment, competitiveness, choice) using a range of data from sensors, games, devices, mobile phones and social networking platforms (Nowicka, 2014).

The Internet of Things (IoT) model is an integrated cloud-oriented architecture of networks, software, sensors, human interfaces and data analytics that are essential for value creation (Harmon, Castro-Leon, & Bhide, 2015). Thus, the use of IoT in a city will integrate the physical, social, IT and community systems of a city so that one can have an integrated view of the city and then service providers shall use information technologies to develop effective urban organisations and systems to engage with citizens and improve the quality of life of its stakeholders.

The argument for sustainable smart cities is that a sustainable smart city increases the capacity of a city and the potential of its resources and capabilities. The capacity of a city should not be seen as its space volume (in three dimensions – length, breadth and depth) but should be measured in five dimensions – three dimensions of space (length, breadth and height), a fourth dimension is time and the fifth dimension is citizens' cultural habits. For example, how can we increase the capacity of transportation roads; three dimensional expansion can be achieved by expanding the road network, i.e. lengthwise, and then underground and overground infrastructure; the fourth dimension expansion of capacity could be by rescheduling time of travel (transport services can be scheduled differently for different people and vehicles) and the fifth dimension of expansion of capacity can be achieved by changing the citizens' cultural habits, for example, advising them for working from home or car sharing or using public transportation and so on. Hence, a designer while designing a smart city should think of efficient, effective and sustainable use of the five dimensions of capacity. The efficiency of a smart city can be measured in domains, such as the right quality of output, the right quantity of output, the right cost of output, the right time of the output and the right flexibility or agility of the system to meet the needs and well-being of its citizens. In smart cities, smart technologies and the IoT and the use of sensors can enhance the ability to receive timely data information and make proactive decisions at the individual, micro and macro level.

As the number of city dwellers increases, the demand for resources also increases. In the future, the limited capacity of the city's housing transportation facilities, roads, healthcare services, energy, water supply, air quality, lands, playgrounds and other facilities will become limited. Hence, limited capacities will bring in the problems of sustainability of the city and to city's ability to meet the people. In such a scenario, we need a city, which is self-intelligent with a brain based on the data infrastructures, so that the city can identify the issues in different domains of the city and respond with the right solutions in real time. Such a city will be a living city and organic city supported by technology, data infrastructure and inclusive participation of its citizens. Such a smart city will have the agility to match supply with demand. For example, if the demand decreases, the city would be able to shrink its capacity and when the demand goes up, the supply will also go up. The demand in a city could be related to means of transportation, energy, housing, parks, road congestion or utility of certain road networks or water harvesting systems. Whenever the supply and demand fluctuate, the sensors and data infrastructure of such a city should be able to respond efficiently, effectively and with sustainability to the planet, people and profit of the city – triple bottom line.

Smart devices, phones, 5G net, Blockchain technology (BT), NFD, cloud computing and IoT are promoting real-world interfaces and applications and can become basic nodes for a smart city digital web infrastructure.

A city planner or a mayor of a city needs the internet to connect the IoT urban system. The data need to be collected for a real-time response from different subsystems of this city. A planer should think of a city as a system with its different facilities as subsystems and integrate them efficiently and effectively. The subsystems include outer space, housing, transportation and mobility, offices, shopping centres and entertainment centres, energy and sustainability and citizens.

Concept of Smart City

A few synonymous, namely 'Smart City' OR 'Smart Cities' OR 'Digital City' OR 'Wired Cities' 'Information City' OR 'Intelligent City' OR 'Knowledge-based City' OR 'Ubiquitous City' OR 'Wired City', etc. have been used in the literature to represent a smart city.

A smart city is a city that uses information and communications technology (ICT) and the IoT, invests in human capital, social capital, technological capital and modern urban infrastructure and services to sense data, analyse, integrate and use *key information* and create sustainable economic growth and high quality of life for citizens and various other stakeholders without compromising transparency, democracy, safety, privacy and security (Harmon et al., 2015). A smart city enables its citizens to use real-time information, communications and digital technologies to create and maintain a resilient, liveable, inclusive, intelligent, and sustainable city for themselves (DoT Govt of India, 2019). Several initiatives have been taken such as Busan (South Korea), Santander (Spain), Chicago (United States) and Milton Keynes (United Kingdom), etc. and several emerging countries, such as India, have taken a pledge to transform existing cities into smart cities.

A city does not become a smart city by just using technology, but the smartness of the city depends on smart citizens, the culture of democratic participation in developing smart city solutions, the education and engagement of citizens in the process of data generation, translation and participation in decision-making. Whereas some studies highlight smart cities with technology as a fundamental requirement, on the other hand, other studies highlight that the fundamental focus of smart cities should be the needs of its citizens or an ecological and green environment. Thus, a smart city is an integrated physical, social, technological and virtual system that utilises the CIT infrastructure, citizens' participation and public-private-enabled infrastructure to efficiently solve and balance the current and futuristic economic, social and environmental development needs of its stakeholders.

A smart city is an organic system that can sense issues, problems and trends in a city and make intelligent solutions to various kinds of needs of various subsystems of a city, such as environmental protection, good livelihood, public safety, e-governance and services, industrial, commercial activities and services. Imagine a city as a complex system constituted of many subsystems and elements. The subsystem can be viewed from multiple perspectives. For example, from a functional perspective, a smart city will be using IoT to address the functional needs of the city through efficient and effective use of resources. Thus, a smart city will have many subsystems, e.g. smart homes, smart transport, smart mobility, smart energy, smart safety, smart physical infrastructure, smart governance, smart education, etc. (See Table 1.1 concept and subsystems and domains of a smart city).

Another way to conceptualise a smart city is that it is a complex system of new smart technology-enabled physical infrastructure, business infrastructure, human capital, social capital, facilities and services, etc. From another perspective, the subsystems of a smart city may include – critical infrastructure components and services of a city – which include city administration, education, healthcare, public safety, real estate, electrical and water distribution, public safety, transportation and utilities.

Thus, a smart city uses information and communication technology (ICT) to connect various subsystems of the city to sense, collect, analyse Big Data, and

Table 1.1. Concept and Subsystems and Domains of a Smart City.

Smart environment	Smart maps	Smart people tracking	Smart health	Smart parking
Smart emergency system	Smart policing	Smart education	Smart entertainment	Smart sustainable governance
Smart industry	Smart water	Smart sewage	Smart parks	Smart retail
Smart infrastructure	Smart employment	Smart citizen	Smart government	Smart mobility transportation
Smart attractions	Smart agriculture	Smart public announcements	Smart weather	Smart housing
Smart energy	Smart innovation	Smart project management	Smart city coordination	Smart tourism
Monitoring of city trees, Air pollution or quality, Water quality, Green spaces	Smart citizens engagement	Crowdsourcing	Smart business	Smart architecture and technologies

then innovatively and intelligently respond to the needs of the city's stakeholders efficiently, effectively and sustainably (Thales, 2021). A smart city continuously improves its potential by effectively utilising IoT/ICT infrastructure, and other resources through participatory government to fuel sustainable economic growth and high quality of life.

A smart city uses its digital infrastructure of digital sensors and digital control systems (such as traffic sensors, building management systems, wearable sensors and devices, cameras and digital utility metres, etc.) for effective management of urban infrastructure.

Smart City as Sustainable City

The United Nations has established 17 Sustainability Development Goals (SDGs) in 2015, for peace and prosperity for people and the planet, present and into future. With this lens, a smart city shall efficiently and effectively address its problems such as capacity, poverty, health and education, inequality, decent work and economic growth, affordable and clean energy, responsible consumption and production, peace justice, partnerships, etc. whilst tackling climate change and preserving our forests and oceans (Ismagilova, Hughes, Dwivedi, & Raman, 2019). Some important domains of sustainable smart cities are shown in hierarchical order in Table 1.2; the lines of the table represent connected networks and the flow of information and decisions.

A smart city sits on ICT/IOT digital infrastructure and soft infrastructure supports and guides the hard infrastructure of such a city.

The smart city is about integrating different components but it is also about thinking about new business models for developing smart cities. How the resources would be raised for investment and cost, and who would pay for all those facilities of the smart city? A smart city is designed for the futuristic trends, issues, challenges and problems of the city. For example, the problems can be related to traffic congestion, travel routes, health and safety, healthcare, ecological and air pollution, waste and water disposal, energy consumption, sustainability of the city, schools and education system, crime rate and gangs, city police, cyber security, tax, adopting modern technologies and methods of living, the harmony of the people, e-governance and various other needs of the stakeholders.

On a continuum of development of a city, when can we say that a city has reached the stage of the smart city? Is it when the city has heavy use of sensors and ICT devices or is it should have some other key performance indicators (KPIs) or metrics? There is no agreement yet on what are the KPIs or metrics to measure the smartness of a smart city. Although there are some attempts made globally to establish a matrix or KPIs of smart cities, certain organisations in Europe and America have commenced awarding cities as 'Smart cities' based on some KPI criteria of smart cities. An organisation named United for Smart Sustainable Cities (U4SSC) has established some KPIs of 'Liveability Standards in Cities' to classify a city as a smart city. These KPIs are based on the United Nations' Millennium Development Goals. Different countries have their own KPIs for

Table 1.2. Important Domains of Sustainable Smart Cities in Hierarchical Order.

Track packages	**Tourist routes and attractions**	**Park and city centre congestion**	**Emergency services and responses**
Smart me	Smart payment	Smart home	Smart car
Visa and access govt services	Find business/ATM	Find transport/ taxi	Utility services payment
Public policy violation	Rent/buy a home	Healthcare emergency services	Education, enterprising and employment
Open data sharing and intelligent, safe, sustainable decisions by devices, e-governance and public-private apps and data security			
Smart safety and crimes	Smart humidity and temperature	Smart technology obsoleteness	Smart ICT connectivity
Smart waste and sanitation	Smart energy grids, sources demand/ supply efficiency	Smart water, rain	Smart open spaces
Smart offices	Smart factories	Smart attraction	Smart sustainable energy
Smart citizen participation	Smart economy and employment	Smart education	Smart housing and inclusiveness
Identity, culture and cohesiveness	Smart healthcare	Smart transportation and mobility	Smart air quality and environment
Data, metrics, measurement of uses, demand, supply, efficiency, sustainability and learning			
ICT/IoT, sensors, devices, data and information			
Social programmes	Ecological environment	Energy	IXT connectivity
Healthcare	Natural resources	Land and space	IoT/ICT
Public safety and police	Heritage sites	Water and waste	Data security and privacy
Education	Citizen engagement	Mobility and transportation	Open and share Big Data

Table 1.2. *(Continued)*

Track packages	Tourist routes and attractions	Park and city centre congestion	Emergency services and responses
Capability of citizens for innovation and enterprise	Citizens and communities, their needs, inclusivity, cohesiveness	Roads, space, parks, buildings, electricity, attractions	ICT/IoT, sensor, devices, data and information
Human capital	Social capital	Physical capital	Technological capital
ICT/IoT, sensors, devices, data and information infrastructure			
	E-governance: Govt agencies and administration	City planning and management	
Leadership and citizen consultations, sustainable smart city business model and strategy			
Happy inclusive sustainable urban life for each			

Sources: CNBC (2017) and Computerworld (2016).

smart cities. For an instance, the Indian government has established 79 indicators to measure the smartness of a city, and all those indicators are based on the United Nations Millennium Development Goals (DoT Govt of India, 2019). India's smart city measurement index is based on four dimensions namely, *institutional and govt; social, health and educational; economic; and physical and ICT infrastructure* index.

The cities' local governments and other institutions are organising competitions such as solar decathlon, smart city designs, how you want your locality, etc. Such competitions award the winners based on KPIs such as the quality of homes and their sustainability, and energy consumption (that the best home will not consume energy more than what it can produce locally from the solar panels on the roof or may wind energy locally). Such competitions even explore (using sensors) the number of people in different rooms, the lights on/off and other utilities, or appliances energy, minimising wastage from the home and minimalising the water consumption and effluents. Thus, the overall aims are to check designs for smart, sustainable and energy-efficient homes.

Case Studies of Smart Cities in the World

New York City (NYC) in the United States has been trying to solve the problem of traffic congestion by using smart science IoT. They have installed several self-serving machines/open kiosks. Using solar power charging Wi-Fi systems people can charge their devices locally as well as can connect to Wi-Fi for free. Also, those devices can provide data to the city planners about the people's traffic, the number of people passing that area and other habits of the people. Such information can be used for planning mobility routes and providing relevant facilities efficiently in the city area. As self-serving machines, the residents or the tourist can check the location and the route of the nearest hotels, the healthcare facilities and use Wi-Fi and charge their phones all free of cost because all that is paid for by advertisements companies using screens on those machines. Similarly, NYC has implemented mobile vehicle connectivity, which means that by using their mobile phone app, they can choose and use a combination of vehicles, e.g. cars, Uber, cycles and public transportation and plan their journey efficiently. New York has used multiple mechanisms for monitoring the traffic, re-organising vehicle speeds, synchronising traffic lights and integrating of range of public and private transportation into one app, etc. for reducing congestion and pollution and effective route planning.

In London, though the mobility of vehicles is quite integrated, one can use apps. However, still there are many gaps for improvement. For example, on London transport road network has dedicated bus lanes, however many times found that bus lanes are not occupied but private vehicles still cannot use those empty lanes due to the threat of penalties. However, using sensor technologies, it will be possible to use all lanes to full capacity by opening and closing bus lanes in real-time. Such action can save investments in additional road widening. Similarly, the traffic lights can be synchronised depending on the priorities and minimise congestion in different areas. Also, in London, there are zero emission zones, low emission zones, congestion charges, etc. those all could be effectively regulated using sensor technology and IoT for the smart cities.

Singapore has already taken a lead in the development of smart city. The city is well-connected to different domains, viz. water supply, power supply, urban mobility from e-commerce, people participation, congestion how to get assistance, public transportation and healthcare. The extensive network of cameras is used to monitor congestion violations, etc. Singapore has also developed a set of apps that can be used by citizens for paying electrical bills, and vehicles, find ATM tracks, taxis, visa applications and other e-governance activities in one place (Computerworld, 2016). The city is utilising the shared economy shared-based business models (SEBMs) for shared offices, shared transportation and shared housing. The whole city is getting integrated so that it can monitor the use of its resources, and demand–supply gaps and accordingly respond to the needs of the people in real-time. The initiatives are taken to increase the density of the city, i.e. the densification of the city as well as to provide sufficient healthcare to elderly people. For example, each home is proposed to have biosensors or monitors to monitor the health pressure on the healthcare centres.

Singapore is using IoT in school and higher education areas too. For example, young minds are motivated to learn IT coding using sensors and robotic technologies. Similarly, courses and modules are designed as one project that integrates science, mathematics and skills related to human beings and teamwork skills, etc. Hence, the educational course/programme could be fully monitored, controlled and the overall management of education could be better. Singaporeans have also tried virtual reality or and the combination of augmented realities to design the layout of cities' infrastructure, buildings, parks, offices, transportation routes and so on, where the simulation is done for different building orientations, their effects on airflow, humidity, temperature, sunlight and shadow zones, and so on. Such virtual reality techniques save a lot of waste in any kind of infrastructure investment because planners can view the possible issues well in advance and take actions to ensure the right air quality, right mobility, right humidity, right noise levels, sunlight, etc. (Computerworld, 2016).

Automatic driving restrictions can be put in place when needed. For this, one must do three things – connect sensors, collect data and interpret data for finding solutions. For example, public green spaces can be effectively irrigated using sensors. Similarly, waste garbage bins are emptied only when they are full. In Helsinki, garbage trucks are outdated methods as the city directly moves garbage underground. A smartphone app enables residents to shape their cities as they deem fit and vote for the choices. The parking lights have inbuilt sensors. Robotic police can help manage the city safely. Businesses can use open data to fight against any corruption and so on.

Similarly, the public utilities, water supply, energy and environment, ecology and pollution, city smart lights and production of sustainable foods, for example, salads, underground and waste disposal could be well-integrated using IoT. Such various domains of the city including playgrounds and building blocks of the city need to be interconnected through sensors, and data infrastructure using Big Data and IoT. Connectivity, speed, accuracy, real-time information, real-time analysis of the data and real-time response to issues and challenges are important actions for effective smart cities.

It is for the citizen of the city to decide how their smart city should look; however, there could be some universal understandings or standards of smart cities. For example, many will agree that a smart city should be sustainable, user-friendly, etc. A smart city should be able to upgrade to new technologies (such as the use of drones and smart cars or driverless cars or automated transportation vehicles, etc.), should be well interconnections of smart houses, hotels should have good interconnections between different IoT in each smart home (e.g. refrigerators, washing machines, energy metres, televisions and other household equipment's and connecting them to sensors for ordering household inputs such as milk or vegetables or other food). Such internal and inter homes sensors can also monitor and control waste effluents from homes and pollution created. Such knowledge can be utilised to put in place a mechanism to decrease the wastage, and pollution at the micro and macro levels of a city.

For example, in Shanghai, China, smart private taxi systems are integrated with headquarters and the live camera feeds guides the taxi drivers for the proper route with less congestion and plan or reroute their journeys. For example, if a customer foresees congestion at one event or shopping centre, they might go to another shopping centre.

The cities like New York are planning their new buildings in such a way to locally produce and use sustainable energy such as solar power, oriented buildings, and wind energy for high-rise buildings thus going forward with sustainable development.

Another model which has been tried in some cities in Europe is sustainably embedding the industrial areas into the residential areas itself. On the one hand, such industrial production is sustainable, green and ecologically friendly; on the other hand, as it is near to houses so it saves transportation (less pollution), and some extra heat energy from such industrial centres can be used for local housing needs. Thus, such integration improves the quality of life, less transportation and gives more time for people to spend with family, etc.

Some old cities in part of the Western world are increasing the capacity of the city by densification of the city, the cities adding additional buildings or adding additional heights to existing buildings or preserving existing heritage buildings and adding extensions in vertical and original frames. Such kind of densification of the city is increasing the capacity of the city to accommodate the swelling population. The local energy production using sustainable energy, e.g. solar, thermal or wind is promoted using building orientations, heights, rooftops, glass facades as photovoltaic solar panels, etc.

Another smart city is Masdar City in Abu Dhabi. The city has been developed just outskirts in the desert area. The unique feature of this city is sustainability. For example, no buildings are more than four storeys, the biggest roads are 6 meter wide and the narrow roads are 4 m wide. The orientation of the building allows positive wind flow, and the sunlight is minimised in the street area, but the ventilation is full. Internal buildings are also quite sustainably designed. Thus overall, it will be a more sustainable smart city that will use less energy. One more attractive point of Masdar city is the electrical driverless underground car pods (Wocomodocs, 2015).

Some cities (e.g. Salzberg Netz) in Europe are using smart energy, where the energy from various sources such as wind, solar, thermal, nuclear, water and other sources is combined to meet the need of the city. The sensor-based technology and AI-based systems monitor the availability of energy and energy consumption. Each home has locally produced energy for their home needs, or business needs as well as for their electrical vehicles.

Elon Musk (CEO, Tesla Motors) is developing a city named Starbase in Texas, USA. A floating city named Busan is being developed in South Korea. Busan city will use the space of the water, aid in avoiding the threat of rising water as it is floating and will use wind and wave energy for energy needs (BDB, 2022). The city will also produce its own food under the sea, its local water supply and an integrated system of safe disposal of waste from the city.

Another big project of a smart sustainable city is coming in Neom City of Saudi Arabia. The project will cost around $500 billion. The city will be 160 km long, three times the size of Texas and will be a fully sustainable smart city (BDB, 2022). The city will have a big floating industrial town and will be housing One million people. The city will have facilities such as a big park, shopping centres and a big artificial moon that will light the whole city using solar and wind energy. The city will be able to produce freshwater from sea water using photovoltaic solar energy.

A Woven City has been developed by Toyota in Japan (BDB, 2022). It will have separate transportation/mobility links, for example, one lane will be dedicated for smart driverless electrical vehicles, the other lane will be for cyclists and the third lane will be full of pedestrians. The city will use hydrogen energy and solar panels for energy. Robots and other sensor technologies will be used to monitor the city, the health and well-being of the people, and the resource needs of the aging population.

Another big upcoming project is Millennium City in the Philippines which will use energy from wind energy and waste material (BDB, 2022). This city will use green spaces and housing and other building areas. The different domains will be monitored using Big Data from energy consumption, weather conditions, air quality, water supply, mobility of the people, weather quality, city congestions, etc.

Smart Cities and Big Data

In smart cities, one more issue is managing the Big Data and related issues of privacy, accessibility, utility, security and safety of the data. Also implementing IoT and installation of sensors requires experts who can manage sensors. Smart cities also need several data analysts who can analyse the Big Data or may use AI (Artificial Intelligence) systems to analyse data, identify the issues in various parts of the city and provide some strategic and operational recommendations.

Data protection and privacy, etc. must be ensured by ensuring that big corporations that are handling the Big Data are in the city-controlled area. There must be a robust control mechanism for data utility, anonymising the data of the citizens. Citizens can be given rights through mobile apps to control the privacy levels of their personal data so that it can be accessed or released depending on the permissions. However, the infrastructure of the data or data infrastructure must be very safe and protected against any cyber hacking or cyber-attacks, as such attacks can lead to blockage of the whole city and its facilities.

Another building block of the smart city is the Big Data (data as oil), and data infrastructure. The first building block of a smart city is IoT-based data infrastructure because all the things are interconnected by utilising data infrastructure. Hence, the soft structure or the backbone of the smart city is data infrastructure. The information and the data are collected using a range of sensors in different areas of the city. For example, imagine the mobility of a person in the city on a typical day and draw profile of citizen's journey. Draw citizen journeys from housing, road transportation mobility, public transportation system, city centres, office spaces, entertainment, health centres, hospitals and healthcare centres, and make is seamless.

Benefits of Smart and Sustainable Cities

Smart cities, on the one hand, improve efficiency and capacity utilisation of a city's existing infrastructure capacity, and on the other hand, it mitigates the need for new investment in increasing the capacities of infrastructures and subsystems of a city (Srinivasan, 2020). It decreases the wastage and pollution levels and improves real-time and faster response to the needs of citizens by responding in real-time to the needs of problems of say city congestions, increasing pollution, water supply, sewage disposal, energy utility, etc. Thus a smart city is an organic, agile, smart, intelligent system that can wisely respond to changes in supply and demands of various utilities, services, resources, and infrastructure of a city.

Sustainable Practices Enabled by Smart Cities

Often there is debate about whether to choose a sustainable city or a smart city. A good understanding is that the goal of a smart city should be to create infrastructure for a sustainable, intelligent, democratic and equitable city for its citizens.

The concept of sustainability can be seen from many dimensions, for an instance, it will be seen from triple bottom line as people, planet and profit, or it can be seen as a city that is equitable, environment-friendly and economic; equitable people oriented means the city is serving the society, equitably (UNECE & ITU, 2021). Equity is not just equal treatment but providing facilities and services in such a way that there is inclusiveness in practice. For example, poor people in many cities may not be able to afford electrical cars, or may not be able to instal solar panels, etc. so how a smart city shall enable such people in participate in sustainable goals? The second dimension of sustainability is about the protection of the ecological environment or planet. It means that we are not polluting our ecological systems, and we are not creating excessive wastages of resources like water, space, energy, etc. This also means we leave our planet with at least the same ecological characteristics, that we received at our birth. The third dimension of a sustainable city is its economic or profit aspect. This economic or profit dimension means not only accounting for profit but also a social profit for its citizens.

The sustainable smart city can also be seen from the perspective of the acronym EPIC, which is *ethical, profitable, integrating citizens and connected*. A smart city achieves its aims by connecting its resources, processes, subsystems and citizens with IoT and sensors. The sensors are the five sense organs of an intelligent city (Hamza, 2021). Hence, an intelligent city should be seen as an intelligent human being i.e., homo-sapiens with five sense organs as sensors that function as its eyes, ear, nose, skin and tongue. The sensors are installed in buildings, on roads, in public places, in parks, on transportation links, on vehicles, on water supply, the distribution system and smartphones, etc. Thus, the information or data from the sensors is sent to the central nervous system of the city which could be the central nervous system, i.e. head of (the data centre) or the peripheral nervous system of the city (local community reaction plan or cloud data centres) (Toli & Murtagh, 2020). The data may be analysed by human beings or by Artificial Intelligence systems to see the patterns, trends, problems, issues depending on what the five sense organs of the city are receiving. Then the central nervous system or peripheral nervous system will decide on a real-time synchronous response to the issues of the stimuli. Hence, the smart city becomes an intelligent sustainable city, which is equitable, democratic and efficient in operations.

IoT and overall data infrastructure or digital infrastructure in the city would have multiple benefits and could be seen by analysing say *Six Thinking Hats* (DeBono, 2019). For example, a *White Hat* will be about collecting and validating data information, the *Yellow Hat* will signify the optimism of positive outcomes, the *Green Hat* will represent additional benefits or spill over benefits, the *Blue Hat* will argue for the processes, procedures and systems – how to do things in the smart city, the *Black Hat* for analysing the negatives issues such as data protection issues, or sustainability issues, or obsoleteness of technologies or any other negative consequences of smart cities and the sixth hat, i.e. *Red Hat* signifies emotions and reactions of its citizens.

Blockchain Technology as a Network and Business Model for Smart Cities

BT is distributed ledger technology (DLT) that includes public, digital, chronological and distributed or centralised ledger for secure, peer-to-peer, distributed online transactions (Salha, El-Hallaq, & Alastal, 2019). This technology allows cryptographically validated transactions recorded in an immutable ledger in a verifiable, secure, transparent and permanent way, with a timestamp and other details and safely stored in distributed nodes. The researchers have argued for the blockchain as a symbol of trust, validating systems, ledgers, currencies, smart contracts and software applications and an integrative operative system, peer-to-peer network, consensus mechanism, art of cryptography, and so on (Nouh & Singh, 2020).

Blockchain is cryptographic technology that enables the exchange of data in the form of secure chained blocks with full security, privacy and trust. Each block in this chain has a unique key that links it to the forward bloc and has a unique code that links it back to the previous block. Thus, blockchain is a quite robust and secure system. This means that if anybody tampers with any block by breaking into the key or the passcode, the data will be lost instantly or the person must simultaneously break into several blocks, which becomes quite difficult to do not impossible. Blockchain uses a crypto (code/Hash) system of information transactions, so the contracts are secure and non-readable unless authorised.

Blockchain will be a good technology for smart cities because this technology aids in overcoming many ICT-related requirements such as flexibility, agility, capex-free, compliance, scalability, trust, security, etc. (Salha et al., 2019).

Blockchain supports a chain of blocks of data or information that allows verifications and secure transactions over the internet with trust. It is giving rise to a new industry – the ‘Trust Industry’ and disrupting and eliminating the traditional intermediaries who were used to create trust between buyers and sellers. For example, a bank while processing a mortgage application needs to check with credit rating agencies, councils, homeowners and various other agencies. Such a process involves several intermediaries, viz. mortgage advisors, solicitors, credit rating genesis, selling, and buying agents, councils, environmental agencies, land revenue registers, tax authorities and so on. So the process of mortgage release often takes longer, and each transaction takes time and cost. However, with the use of blockchain technology, the information can be shared insatiately and simultaneously among different stakeholders with end-to-end encryption and without the need of any third party acting as an agent of trust or the verification of the documents. Thus, BT has the potential to de-intermediating many industries and the buyers (service user, customer, citizen or endpoint) and the sellers (supplier, source) will be able to contact directly, safely, securely and with concrete trust. Such technology will add excellent value to the efficiency and effectiveness of smart cities. The different domains of a smart city can be very well networked.

BT is used in diverse fields such as the financial market, transportation, business and commerce, supply chain management, energy sector, and hence in smart cities too.

BT for smart cities offers several advantages, such as transparency and connectivity, direct communication between the stakeholders, integrity and trust, overall efficiency, more critical participation, effective management of information and creation of digital currency as spill over benefits to the city (Iberdrola, 2021).

To understand the working of blockchain and its ripple effects as a self-supporting business model, BT-producing companies have their own business model; the usage of BT creates safe transactions and the storage of, and analysis of information creates cryptocurrencies such as Bitcoins. BT allows peer-to-peer sharing of information across several participants in the blockchain network. It also creates opportunities for stakeholders to store, and search data and information and undertake the environmentally and physically arduous process of block building ('mining'). The companies or providers are incentivised by providing them opportunities to undertake digital mining. This means that the suppliers or providers of technologies or data warehouses or electricity suppliers to the data warehouse are paid rent for storing or analysing the data and information in the form of digital currency or cryptocurrency or bitcoins. Hence, BT has two main benefits: it provides a network for safe secure trustworthy multiple distributed data blocks and it also provides digital currency which is valuable in the real world. This means a smart city on BT can self-sustain its revenue-cost model, as additional revenue will come from so-created cryptocurrencies from BT platforms in the city.

BT is this technology that improves trust in any transaction, as we have discussed in the previous sections that building a smart city requires a lot of participation of different stakeholders and citizens over the Internet with a top down as well as bottom-up approach. In such a scenario, having authentic information, trustworthy data, unique information, privacy and security of information, faster transactions, distributive data and mechanisms of effective decision-making, etc. are especially important. BToffers such an opportunity for the reliable, trustworthy, peer-to-peer, secure transaction of information and among different subsystems of a city and various stakeholders for making effective decisions. Hence, BT has an immense potential to solve several issues related to the design and development of effective sustainable smart cities.

Not only that BT offers technology for connecting communities but also BT offers an effective business model of revenue streams. Not only the blockchain will ensure fast and effective exchange of information using the blockchain network but also the same time BT generates cryptocurrency-related benefits for those companies or people who invest in cryptocurrency (e.g. Bitcoin). The BT data mining will create digital currencies and such currencies can be traded as money. Thus, BT has dual benefits; the main benefit is transactions and transfer of trustworthy information for decision-making for the city and the secondary benefit will be a generation of digital currency or cryptocurrency or currency tokenisation. Such additional spill over applications, such as tokenisation or mining digital currency, may provide additional streams of revenue for businesses. A token community could open myriad possibilities for citizens. Tokens can be used to pay for services and products in smart cities (Deolite, 2022).

Hence, a business model of smart cities based on Bitcoin based on the BT will also support financially in the development of physical as well as blockchain-based infrastructure for a smart city.

BT is a trustworthy transactional ledger; it means the ownership rights of any physical properties, intellectual property, data, and any asset can be uniquely assigned to specific people who legally own it. This very process increases the trust of buyers and sellers in any transaction in any economy locally or globally. For example, imagine if a house in a city has solar panels and they are producing electricity more than what is consumed at home, the extra production can be sold locally to another home, or another business and the payment can be transferred directly back to the supplier house using BT and without any need of any intermediary. Similarly, the supply chain in any city can be well-integrated, with clear traceability and responsibility at various stages of product or service delivery. This also means any person who buys anything in any retail store (e.g. organic bananas), etc. can credibly ensure and trust the origin and originality of organic bananas. Similarly, various domains in the smart city such as smart affluent, smart policing, smart sewage, smart electricity, water supply, smart mobility, smart health, smart citizens, etc. can be traced and tracked effectively using BT.

BT can solve issues with city transport by offering mobility as a service with payment and the mobility can be seamless between different means of travelling, viz. wheels chairs, cycles, taxis, public transportation, trains, airlines and so on (Deolite, 2022). BT can be used in the water distribution system, water harvesting structures and supply and selling of water not only by centralised authorities but also by local communities (additional surplus water from home-based rainwater harvesting structures). The payment for such surplus resources (water, less CO2 emissions, renewal energy, car as a taxi, parking place, child minding services, etc. from each home or business) can be directly made to the relevant suppliers using credibility and trust of contracts offered by the BT. Public administration services in the smart city such as e-governance, land registries, identity management and authentication, tax collection and records management, etc. can be automated more security as the authenticity of owner/start and buyer/endpoints can be verified using secure, trustworthy transaction. Any kind of violation of regulations say as traffic rules, waste disposals, parking or any other thing can be traced back directly to the person and responsibilities can be fixed and penalties can be safely secured. It means any subsystem of a smart city, viz. smart housing, smart energy, smart health, smart water, smart education, smart transport and mobility network, smart economy, smart businesses, sustainable actions and so on, can be integrated with trust in transactions using BT.

One issue with blockchain is the excessive use of energy by data warehouses and the effluent of heat and carbon footprints, etc. This area needs attention, and we need more efficient models for data warehouses and data mining from BT.

Planning and Development of Sustainable Smart Cities

The smart city could be designed from scratch (greenfield investment), or the existing cities may be redesigned and developed (brownfield) as smart cities. The designer should consider trends in population growth/changes and usage of city infrastructure for the near future. One should plan, design and develop the smart city by applying different principles of design, e.g. design thinking, systems thinking, form and function, simplicity, emotional appeal, liveability, socio-cultural design and intersections between urban planning, design and ICT design, etc. (DoT Govt of India, 2019). A superior design of a smart city requires assessing the needs of ICT/IoT and digital infrastructures, ICT skill sets, community engagement and cyber security infrastructure, etc. The implementation requires implementing the physical and ICT infrastructure, installing sensors/ devices across the resources, executing physical infrastructure and connecting communities. The next phase will include collecting data from sensors, sharing open data or analysed data/information with various stakeholders, e.g. e-government businesses, business organisation, technology companies and citizens, etc. to use data to decide. And the last phase will be actively using the IoT capabilities to make real-time decisions.

Needs of Policies and Digital Infrastructure for Developing a Smart City

Countries in Asia, the Americas and the EU are considering creativity and innovation, global competitiveness and sustainability as the main driving force behind the development of smart cities. Smart cities need smart cities policies, strategies and business modelling – to increase awareness, and guide stakeholders and investors in developing their strategies, business models, public – private partnerships and plans for the successful execution of their projects for developing smart cities (Harmon et al., 2015). Hence, the national, regional and city governments need to set Innovation and Competitive Policies – for the knowledge economy; Labour Market Policy – to sustain employment, facilitate social cohesion, and reduce poverty; Smart City Digital Infrastructure Policy – to attract specialists and stakeholders to work for smart cities; and Data Policy – for safely, securely sharing Big Data along with protection of privacy (Harmon et al., 2015). Smart cities also need a Sustainable Development Policy – for smart, efficient and effective use of resources – land and space, energy, reducing water use, reducing greenhouse gases emissions and a Policy on the Digital literacy of the Stakeholders – for users to be aware of how to use the technology safely and securely (Harmon et al., 2015).

Social Economy-Based Business Model

A business model is a configuration of revenue and cost streams to create and capture customer value, the ways of organising processes to make money and generate and capture value (Baden-Fuller & Morgan, 2010; Verma, 2017).

SEBM could be the best approach for developing, maintaining and enhancing smart cities (Dadwal, Jamal, Harris, Brown, & Raudhah, 2019). Such participatory and community-based models of smart cities will deepen democracy and develop a resilient, innovative ecosystem in the city. Further, the SEBM will ensure that all resources are shared in real-time; demand–supply is well matched; and the resources will be used to maximum capacity and shared among stakeholders (Barbu, Ştefan, & Sirbu, 2018; Olofsson & Farr, 2006). A business model is a simplified and aggregated representation of the relevant activities of an organisation and sustainable business models will consider the needs of multi-stakeholder with the aim of creation of monetary and non-monetary value for a broad range of stakeholders and hold a long-term perspective while balancing the triple bottom line – profit, planet and people (Shetty, Renukappa, Subashini, & Khaled, 2019).

The flow of antecedents and consequences are multidimensional multi-directional; hence, such a system requires a huge amount of data management, data analysis and then taking proactive or reactive actions. This brings us to another point related to the budget or cost of creating and maintaining sustainable smart cities. Who shall pay for infrastructure? Who shall pay for sensors? How the electricity or energy will be supplied to the sensors? Is the smart city creating more energy issues and more waste? How shall we meet the need for human resources; who will manage Big Data? What can be the best sustainable business model for smart cities? Such questions are mostly related to potential business models for smart cities.

One business model can be that the entire project should be publicly funded by the citizens and go for centralised action planning. The opposite point of view is that projects shall start at the bottom of the pyramid and communities create the system and make decisions. The latter operational model requires that the data from the data centres is freely available to the communities and the communities, private small and large companies use this Big Data and analyse it using their smart devices and make decisions for themselves. For example, a citizen might plan their mobility route during office hours, they can know in advance if a bus is overcrowded and which route, they should follow, etc. The sustainable equitable democratic city should be based on a bottom-up approach, where the communities participate in planning and executing sustainable smart cities for themselves a city which they want to live in the central idea is that as the smart city is for the people the city, so the city should be servient to the people not for the technology. Hence, it requires people's participation and engagement and often in cities citizens are too busy to participate in the city's activities or community activities. So it is important to increase the awareness of the people to engage themselves and participate in organically developing their city or their villages into smart sustainable intelligent places to live happily.

A connected city can use data from one domain of the city as a leading indicator to address the needs of another domain of the city. Imagine a city has installed sensors to measure the flow of rainwater. This information can become a leading indicator for many other things, such as water disposal systems, planning for transportation routes due to flooding, for waste disposal after the floods; this, in turn, can become a further indicator of energy or electricity problems in the city due to rains and flooding, further such inputs can trigger opening or closing of schools and offices and so on. Similarly, the sensors in the solar panel can aid in weather forecasting (solar panel functioning depends upon solar conditions). It can also be an indicator of the amount of electricity produced and consumed and such information can also lead to further redesigning the buildings for effective sunlight or airflow in the city that in turn can be key indicators of designing of transportation roads and other networks and so on. Hence, the basic argument is that a smart intelligent system should be a well-integrated system, a collective system with a collective intelligence of communities. In such a collective intelligence, there are many layers and many independent and dependent variables.

Smart City Digital Infrastructure Business Models Require

(1) The high-capacity broadband infrastructure of cable, optical fibre and wireless networks.
(2) Physical ICT/IoT infrastructure embedded digital systems, smart devices, cameras, sensors and actuators for real-time information processing (Maheswar et al., 2021).
(3) Software Applications to enable real-time communications and collaboration to enable engagement between citizens, institutions, and businesses.
(4) Data warehouse canters for centralised or distributed sensing, collecting, storage, analysing dissemination and utilisation of Big Data safely and effectively.
(5) Technical human resources task force centre led by City Digital Officer – for planning, implementation and coordinating the digital infrastructure and proactively or reactively solving issues with digital infrastructure and protecting against data breaches or cyber-attacks, etc.

Challenges in Developing Smart Sustainable Cities

(1) *Financial Requirements*: developing physical and city infrastructure, IoT devices and sensors installing them, the safety of the infrastructure extra requires a huge amount of financial support budgets, which normally is not easy for least of all countries and developing countries.
(2) *Technological Availability*: in many countries, there is a dearth of the right technologies which can be used in smart cities are the technologies in our absence are not available locally or are too expensive to import (Maheswar et al., 2021).
(3) *Data Analysis and the Skills Need*: another challenge in developing smart cities is having people with the skills who can analyse Big Data. Big Data is huge, continuously collected and accumulated and often complex and always changing data sets, i.e. machine-generated data from sensors, accelerometers, ambient light sensors, GPS, proximity sensors, gyroscopes, pressure sensors or devices, cameras, smart phones or social media sites or apps. The big challenge is to store these data safely, retrieve, analyse and use it. Data analysis and predictive modelling require a range of data science skills, to analyse, visualise and make sense of the data and such skill sets and trained people are in short supply.
(4) *Physical Infrastructure Bottlenecks*: in many cities of the world, particularly in the developing and least developed countries, the growth of population and immigration to cities is increasingly at a much higher rate than the size and the capacity of the city. So infrastructure is already crippling, and the cities are not fully ready to even start a smart city project.
(5) *Lack of Awareness about Sustainability and Limited Engagement of Communities for Developing Sustainable Smart Cities:* The proactive and reactive actions of all the smart cities and the cities' intelligence depend on the engagement and participation of local citizens and communities. It needs a balance between the ecology of the planet and the physical and natural sources of the city, and it should be economically and socially profitable for the city (Maheswar et al., 2021). Hence, many cities have design matrices (KPIs) for measuring the amount of sustainable smart cities. The KPIs are some combinations of social indexes, economic indexes, ecological contact indexes, political indexes and technological indexes. All these indices collectively are useful only if the participants, i.e. citizens actively participate in city development and engage with the data and information to make the decisions. However, it has been found in many parts of the world that the citizens do not engage in city planning, designing or any activities related smart city because of several reasons, viz. lack of time, lack of motivation or lack of abilities, etc. The engagement of the citizens can be enhanced by different mechanisms of e-governance, e-planning, e-participation, -communities, citizens e-activism, e-planning, urban informatics, urban commuting, city-mediated training and community development, etc.

(6) *Collaborative and Social Economy-Based Business Models*: another challenge in developing and designing sustainable smart cities is creating a collaborative social economy. Such economies will use collaborative and SEBMs, crowdsourcing of the data crowd intelligence, sharing resources and infrastructure, crowdfunding and crowd planning and crowd action and so on. However, creating such a collaborative social economy is a new challenge as it needs people's social and cultural capabilities. Intentions to change your cultural and social habits, new legal frameworks and policies related to collaborative social economies (Dadwal et al., 2019). The governments at the local and the regional level must develop legal frameworks and procedures and policies related to the effective working of SEBMs. It requires paradigm shifts in innovations and industry outlooks from the governments. They need to invent business models analogous to the companies like Uber or Airbnb. Such companies do not have physical infrastructure related to their domains of action, but they are hugely successful (e.g. Airbnb offers hotel rooms, but they do not own any rooms or hotels and Uber do not own cars, but they are known as a taxi company). It will be about thinking of private and public resources and infrastructure and sharing them in real-time; it will be about communities looking for their spare resources and facilities and then making them available at a cost of the rent. For example, one hospital in the city might have some spare beds or spare machines, which can be used by another hospital in real-time. It will be all about a platform that ensures the flow of information about the demand and supply and matching the demand with supply efficiently, thus using the resources to full capacity.

(7) *Smart Cities Top-Down or Bottom-Up Approach and Coordination*: another challenge in the design development of smart cities is what approach to be taken. Top-bottom approach means the ideas come from the top of the organisation and penetrate down to the societies, whereas the bottom-up approach is just the opposite. In many democracies, and advanced countries, the bottom-up approach has been quite successful in engaging local communities in the decision-making process using the data collected from sensors and other IoT devices. However, in many least-developed countries (LDCs) and developing countries the top-down approach has been applied with lesser success and ineffectively (Höjer & Wangel, 2014). So LDCs and developing countries must figure out what kind of approach will work in their cities. The decision making approach can depend on the local culture, the practices and values and beliefs of the people of that city and the international cultures (such as power dominance vs. equality, uncertainty avoidance, individualism/collectivism, masculinity/femininity and long-term orientation/short term, indulgence vs conservatism, etc) (Hofstede, 1997).

(8) *Data, Devices, and Information Standardisation*: the data from different sensors and devices could differ by its nature, units of measurement, quality and consistency, errors, etc. The data and information which is coming from various sensors, for example, humidity measurement sensors, healthcare sensors, water supply sensors, cameras, smart cars, traffic pictures, etc.

are often in different forms and different measurement units, etc. So it becomes exceedingly difficult to compare data or integrate data to make a comprehensive decision. This will be a big challenge for upcoming smart cities because the data types, their nature, their units of measurement and their qualitative or quantitative nature are quite diverse. It will be difficult to first convert data to the same standards and then make decisions (Clarindo, Pedro, Castro, & Aguiar, 2021). For example, if a city wants to see transportation mobility the data from the cameras will be as pictures, the data on air quality could be analogical or digital and the data for humidity and environment could be still in different forms and units. Hence, in such a situation, taking a collective decision on road transportation is quite difficult unless the data is standardised from old sensors and sources into one form and then becomes compatible to view the patterns, trends and any other issues.

(9) *Multi-Mode Data Fusion Model Construction*: the multi-source, heterogeneous, time-varying, and multi-dimensional characteristics of city information have brought great difficulties to data fusion. Hence, the design and development of smart cities must consider a multi-modal data fusion model: service information, description model, metadata model and interface model mode (Bingzhao, 2021).

(10) *Technology Taking Lead Over Citizens' Needs and Sustainability*: one more challenge of developing smart cities is that often, the designers are bogged down by technologies and they think everything from the technological paradigms. The central idea should be that a smart city is for the people, by the people and not for the technology, by the technology.

(11) *Collaboration, Communities and Culture*: smart cities are not just IT infrastructures or physical infrastructures. The basic premise of sustainable smart cities is to provide a liveable city for their citizens (Maheswar et al., 2021). However, the development of smart cities requires collaboration and coordination between various government departments, engineers, designers, city planners, public-private partnerships, device apps, business organisations and most importantly the citizens.

The citizens have their own national culture and value system, and the smart city would have its own culture and value system. Such differences can often lead to a clash among stakeholders. Many times, a smart city may focus more on efficiency and capacity and may ignore the need of cultural reorientation of its citizens. For instance, it took years in India to avoid the practice of open defecation and adopt a clean India campaign (*Swatsh Bharat*). So many times, it is often difficult to implement innovative ideas with new ethical and efficiency principles, when communities have different local culture and values.

(12) *Adoption of Smart City Models*: in line with the diffusion of innovation theory the process of design, development, implementation and adoption of smart cities depends upon the quality of physical, social and ICT infrastructure and the relative advantage, compatibility, complexity, trial-ability,

cost, evidence of efficacy, level of risk of the innovative technology (Curry, Dustdar, Sheng, & Sheth, 2016).

(13) *Ethics and Citizens' Rights*: Developing smart cities also get pushback from non-governmental organisations (NGOs) and citizen's rights bodies. The various counterarguments such as use of technology will replace human beings, jobs could be lost, technology may overrule the human mind, movement of resources and employment to other countries, multinational corporations (MNCs) may undertake some unethical practices in pushing their technologies, etc. are put forward. Further, the issues related to data security, data breaches and national security etc. are also put forward as arguments against the development of smart cities. Also smart cities can cause ethical issues of the digital divide between different communities, between rich and poor and between different ethnicities, and groups. Those who have more access to digital literacy and technology will be more empowered than others (Höjer & Wangel, 2014). Also, the sole focus on efficiency and capacity of the city can lead to giving more importance to the value of efficiency and compromising the other values of human beings (such as happiness, slow life and relaxation). Western societies assign more value to efficiency; however people in many eastern or southern countries may give more importance to their other value systems. So, while designing smart cities, the designers must decide which ethical values should be given priority. There will be issues related to the values of equity and inclusiveness. For example, a poor person may not have access to smartphones or electric vehicles or solar panels or housing or schools in such diverse and divided societies, so the poor people cannot participate, and cannot take the benefits of smart cities.

(14) *Data Safety, Privacy, Security and Cyber-Attacks*: one of the big challenges of developing sustainable smart cities is safely storing and using the data. The Big Data needs to be stored, shared and used according to data protection laws such as GDPR (General Data Protection Regulation). It requires robust policies, processes and systems for storing, sharing, using and disposing of the data safely and securely while maintaining the accessibility and privacy of the people. Because Big Data shall be open Big Data, so that Big Data can be assessed from any mobile or device, hence such an open system is prone to cyber-attacks. Such data breaches or cyberattacks can cripple the whole infrastructure of the city. Cyber-attacks can adversely affect communication networks, transportation networks, power, and electricity and so on. Hence, governments and administrators need to ensure the safety, privacy, transparency and equitable availability of the data and information to all stakeholders without compromising any physical, psychological, economic or social or life threats to its citizens. Thus, creating and maintaining a *Cyber Security Framework for a Smart Sustainable City is Challenging*. The government must ensure a strong cyber

security framework that includes the participation of different stakeholders so that the cyber security is taking care of any risks, access to the latest data, privacy breaches and cyber-attacks and their risks. Such a framework should also include education and awareness of citizens about sharing and using the data safely and securely.

Designing Smart Sustainable Cities

Leaders and strategists should consider design thinking, systems and future thinking approaches, when planning, designing and implementing ICT for smart cities. The design thinking approach is a user's needs-centric, agile, innovative, integrative system and futuristic orientation to designs. The aims of a liveable, sustainable, smart and intelligent city shall be determined by involving various stakeholders and addressing various operational, financial, technical, regulatory, social, ecological, economic and business model feasibilities. The stakeholders such as citizens, governments, administrators, industry-service providers like investors, technology and infrastructure organisations must be involved in the process. The process will be multistage. It also involves understanding users through building personas and their daily journeys in the city.

In the first stage, set the mission, vision, values and objectives of smart cities. That shall lead to the development of overall strategy, policies and business models for the city. This shall further feed into the preparation for physical and ICT infrastructure plans, systems and subsystems, regulatory policies and procedures, procurement policies and procedures, and project feasibility studies, etc. (Clarindo et al., 2021).

The second stage will be about implementing and executing smart city plans.

At this stage, consider the use of ICT technologies along with other technologies such as BT, fog computing, cognitive analytics, deep learning, artificial intelligence and others (Fu, Jia, & Hao, 2015).

The visual design and functional design can be crossed with physical and digital components to arrive at different layers of design of a smart city (see Table 1.3).

Smart Cities and Cloud Computing

Smart cities use a range of Big Data related to various domains such as the land use, environment, socio-economic, economic activities, energy, transport, city attractions, water and sewage, public health, participatory governance, citizen movements, citizen services and so on. Thus, an integrated perspective of generating, storing and utilisation of Big Data is required for the science, policy, planning, governance and business questions that will aid in decision-making in smart sustainable city (Khan, Anjum, Soomro, & Tahir, 2011).

Smart cities require applications, platforms and infrastructure that connects, manages and optimises the data from many complex sets of devices, sensors, people and software, etc. for a real-time information analysis and intelligence. The aim is to transform the urban environment and address the needs of citizens.

Table 1.3. ICT/IoT Elements of Smart City Design.

	Physical ICT	Digital ICT
Visual design (looks)	Product design Hardwares, devices, sensors, communication gateways, servers	Visual interface designs of apps and systems
Functional design (works)	Process and system design User-centric and need-driven functions in the design	Software, systems and interfaces Interaction, experience and navigation design, security, discoverability, computational designs

Such an amount of Big Data requires high storage capacity, security, highest performance computing power, scalable cloud architecture (stream analyst, machine learning, Hadoop, Spark, etc.), efficient economic modelling, environmental sustainability and agility and so on. Hence a cloud-based IT infrastructure could be a satisfactory solution for smart cities.

The main pillars of smart cities such as; smart people, smart economy, smart environment, smart governance and smart mobility, etc. contribute towards the sustainability of resources and resilience against increasing urban demands. The multidimensional problems of smart cities require an integrated approach of data acquisition, integration, processing and analysis mechanisms to share information for the resilience and sustainability of a smart city. The cloud environment can provide an opportunity to integrate the Big Data from various sources, and process and analyse the data in acceptable periods and formats. Cloud computing offers an incredibly helpful solution to address the challenges of traditional localised data, apps and IT infrastructure.

To address the needs of agility, flexibility and continuous demand of ever-increasing infrastructure investment, smart cities should use cloud-based IT infrastructure and computing, cloud-based infrastructure, platforms, and applications, etc. [IaaS, PaaS, SaaS] (Clement, McKee, & Xu, 2017). The cloud-based service offers economic benefits such as on-demand services and resources (e.g. storage, processing power, memory, bandwidth), speed, agility, flexibility, broad network access across devices and platforms, better information sharing and collaboration through the heterogeneous, location dependent access, rapid elasticity as per demand or scale, ease in measuring and monitoring KPIs, innovation and access to new and emerging technologies, etc. (Kakderi, Komninos, & Tsarchopoulos, 2016a). Cloud services will offer flexibility in the system to upgrade the infrastructure, platform and applications as per modern technologies as well as per the expanding demand from different domains of a city (Kakderi, Komninos, & Tsarchopoulos, 2016b). So a cloud-based system will also offer opportunities for better service, low cost, high-quality services, ability to manage large-scale heterogeneous data, better sourcing and applying public-private partnership model and safer and secure data and infrastructure (HPE, 2022).

The cloud-based infrastructure could be of many types. The cloud infrastructure could be exclusively for the internal application of an organisation [*Private Cloud*], or could be exclusively used by multiple organisations that have similar interests for collaboration [*Community Cloud*], or a cloud-based an open source technologies and solutions [*STORM cloud*] or a general public access infrastructure for open use [*Public Cloud*], or Government based clouds [G*clouds*] or a combination of all private community and public infrastructure [*Hybrid Cloud*] (Songhorabadi, Rahimi, Mahdi, Farid, & Kashani, 2016). A cloud-based services provider could be also of many kinds of services. The cloud services may consist of services for consumer applications on the cloud [Software-as-a-Service -SaaS]; or may develop a platform to create, test or host new applications [Platform-as-a-Service -PaaS]; and/or may provision the for the network, fundamental computing resources, and customising computing environment [Infrastructure-as-a-Service -IaaS] (Kakderi et al., 2016a).

The cloud-based applications can run on a public cloud such as Amazon Web Services, or Microsoft Azure, etc. and can provide computational resources on a pay-per-use basis; however, such public clouds can lead to challenges in implementing public-private partnership models. For example, usage of such public clouds can lead to issues related to proprietorship, customer lock-in costs, global nature, data storage location boundaries, and issues related to safety, security and sovereignty of national infrastructure (Dener, 2019). The other options of cloud-based services may include open-source platforms or radical platforms which are the combination of social network platforms and the IoT. Such cloud base services could use the data from social networks and may engage the citizens more in the process of data generation, information sharing and decision-making for smart cities.

However, a cloud-based infrastructure can face a range of issues related to legality and security threats. For example, there could be issues of difficulty of use, the vulnerable data transmission, insecure API (application programming interface), malicious data loss, data breach, authentication and authorisation issues, virtualisation of security and so on. Similarly, on the legal front, there can be challenges related to regulatory and standard compliance, the vulnerability of virtualisation of technologies, ensuring data integrity and other regulations related to security checks, etc.

Strategic Map to Migrate the Smart City Into Cloud

To change the existing infrastructure into a cloud-based infrastructure, platform and applications, etc. a multistage stage process should be followed. The process of implementing and migrating the city's IT infrastructure to a cloud includes the management of multiple layers of physical infrastructure, hardware, IT infrastructures and applications, etc. (Kakderi et al., 2019). Table 1.4, cloud

Table 1.4. Hierarchy of Levels/Layers of a Cloud Infrastructure for Smart Cities.

Levels/Layers	**Cloud Infrastructure for Smart Cities**		
Service Layer Business	**Platform as Service Layer:** PaaS provides for the development, testing, deployment, management and maintenance of application development (WS Elastic, Microsoft Azure, Google App Engine, Salesforce, Cloud Foundry, etc.)	**Administrative Layer:** Provides to the platform's administrators and to the application owners the tools that allow them to manage and monitor the components of the platform, as well as the Smart City applications	**Access Layer:** The front-end for the Smart City services. It receives the http(s) requests from users and redirects them to the suitable application's VM
Service Layer for Applications			**Application Virtual Machine Layer:** Host the Smart City Application on City Governance, Innovation Economy and Quality of Life, etc., e.g. Virtual City Market, have you Say, Cloud Funding, City Branding, Road's crowding, crimes, city attractions
Cognitive Computing Layer	Interactive exploratory layer for users processes the data for application-specific purposes using data browser; analytical engines Big Data mining; data processing; data analytics; queries		
Cognitive Computing Layer	The resource data mapping and linking layer: Data mapping data interrelation service composition		
Data Layer	Data acquisition, cleansing and classification using standard approaches such as APIs or OGC: Data, meta data source classification, data cleansing.		
Data Layer	Data Service Layer: Contains database and the file servers, both deployed on VM clusters and provide high-availability and scalability (e.g. MySQL and PostgreSQL)		

Table 1.4. *(Continued)*

Levels/Layers	Cloud Infrastructure for Smart Cities
IoT Network Layer	Infrastructure as service layer IaaS: A cloud-based virtual operating system that controls large pools of *computing*, *storage*, and *networking* resources (the hardware), and virtual machines, and gives administrators several tools to deploy their applications.
IoT Network OS Layer	Operating System: Manages the operation, execution and processes of virtual machines, virtual servers and virtual infrastructure, as well as the back-end hardware and software resources public (AWS, Azure) or open source (Linux Enterprise Server, Red Hat Enterprise Linux, etc.).
IoT Device Layer	Hardware Layer: Physical resources (i.e. servers, storage, network, sensors, devices, cameras, etc.) that hosts the platform.
Physical Infrastructure and Resources of the City	City geography and physical infrastructure and facilities – e.g. city domains (smart economy, smart infrastructures, smart governance, smart health, etc.) that deal with various challenges of the urban environment (investment attraction and entrepreneurship, mobility, education, waste management, etc.).

Sources: Dener (2019) and Nowicka (2014).

infrastructure for smart cities, illustrates different layers of a cloud-based IT infrastructure for a smart city (HPE, 2022).

To start with the process of implementation of a cloud-based IT infrastructure, first, the IoT planners need to determine the strategic aims and overall objectives of the smart city (e.g. city governance, info structure capacity, sustainable environment, innovation economy and quality of life) and determine the overarching data storage requirements. They need to take a stock of the existing city, its population, facilities and infrastructure, etc. (SWOT – strength, weakness, opportunities and threats). The process should also involve engagement with key stakeholders (internal – legal, IT, budget/financial, procurement and external – citizens, community groups, business associations, NGOs, cloud service providers, etc.) and identify the needs and powers of various stakeholders (see Table 1.4).

At the first stage, based on the need analysis and overall strategic aims of the city, relevant services and applications to be used and cloudified/or migrated to the cloud is identified. This needs analysis also provides basic information for the identification of requirements related to the operating systems, programing languages, databases, web/app services, frameworks, application lifecycle tools, etc. Thus, at the end of this stage, the applications of services to be migrated to the cloud are selected.

In the second stage, the relevant cloud service environment should be selected. It includes the selection of the type of cloud environment (IaaS, PaaS, SaaS), the selection of the cloud development model (public, private, hybrid, community) and relevant technologies as well as the selection of the cloud service provider. While selecting a cloud service environment, due diligence should be paid to expected service levels, ease of use, social norms, support needed, security, privacy, open standards, transportability, interoperate ability, compatibility, cost, time, quality, flexibility, redundancy, innovativeness and continuous improvability of the technologies.

So the second stage ends with the technical or procedural problem adaptation. This will be about the deployment of relevant applications to the new platform and IT infrastructure.

The third stage shall involve deciding hosting environment, network configuration and connectivity, supplementing search services such as SMTP, DNS, WWW and architecture (e.g. use of resources, underlining technologies, licences and security mechanisms). One must evaluate the readiness, customisability, legal compliance, service architecture, easy installations and innovativeness of the applications. The process requires the adaptation of application services as per local needs, the deployment of the services and apps, testing of the apps, improving the apps and finally transporting the apps to the cloud environment.

The fourth stage of implementing cloud computing for smart cities involves the administration of services and applications and IT infrastructure. The process includes administration of its applications, cloud environment, data analytics, Big Data management, backup services, and ensuring the operability of the applications and the infrastructure. The jobs of administration at this stage include overall data management – data collection, safe storage of data, data protection, security, privacy, accessibility, ownership of the data, regulation and compliance.

The last phase of implementing cloud-based city services includes the actions related to validations of the data, applications, infrastructure and cloud environment to monitor the effectiveness of service and take corrective and preventive actions.

Conclusions

A range of pull and push factors such as the demand of the increasing population, technological innovations, deteriorating ecological environment, changing society's needs and limited resources are leading to human beings thinking of innovative solutions to their living challenges and problems. As civilization has evolved, humanity has moved from forests to villages, then to cities, and now to smart cities as well as cities in outer space. A smart city uses ICT, IoT, sensors and devices to connect various subsystems, viz. smart infrastructure, smart transport, smart mobility, smart homes, smart energy, smart parking, smart parks, smart business centres and other domains of the city to sense information and collect, analyse Big Data and then innovatively and intelligently respond to the needs of the city's stakeholders efficiently, effectively, democratically and sustainably.

The smart city is about integrating different components but also it is about thinking about new business models for developing smart cities. There are several challenges and needs, viz. new government policies, high-capacity broadband, managing Big Data, data privacy, community participation, choice of right infrastructure and technologies and experts that must be addressed while designing and developing smart cities. City planners can make use of emerging ICT, BT, cloud computing, IoT and community-based SEBMs to design and develop smart cities for the future.

References

Baden-Fuller, C., & Morgan, M. S. (2010). Business models as models. *Long Range Planning*, *43*(2–3), 156–171. doi:10.1016/j.lrp.2010.02.005

Barbu, C. M., Ştefan, B. R., & Sirbu, E. M. (2018). Business models of the sharing economy. *Review of International Comparative Management*, *19*(2), 154–166. doi: 10.24818/RMCI.2018.2.154. Bucharest University of Economic Studies.

BDB. (2022). World's Future Megaprojects by 2035 (Smart Cities) – YouTube. Retrieved from https://www.youtube.com/watch?v=1vxYHwuvIGc. Accessed on 11 November 2022.

Bingzhao, S. (2021). Construction of smart city cloud platform based on multi-mode data fusion model. *Journal of Physics: Conference Series*. doi:10.1088/1742-6596/1744/3/032028

Clarindo, J. P., Pedro, J., Castro, C., & Aguiar, C. D. (2021). Combining fog and cloud computing to support spatial analytics in smart cities. *Journal of Information and Data Management*, *12*(4), 342–360. Retrieved from https://repositorio.usp.br/directbitstream/1e54592e-af5b-4354-b80b-1063867d5576/3050561.pdf. Accessed on 10 November 2022.

Clement, S. J., McKee, D. W., & Xu, J. (2017). Service-oriented reference architecture for smart cities. In Proceedings – 11th IEEE International Symposium on Service-Oriented System Engineering, SOSE 2017 (pp. 81–85). Institute of Electrical and Electronics Engineers Inc. doi:10.1109/SOSE.2017.29

CNBC. (2017). What is a smart city? | CNBC explains – YouTube. Retrieved from https://www.youtube.com/watch?v=bANfnYDTzxE. Accessed on 11 November 2022.

Computerworld. (2016). Smart cities: Singapore – YouTube. Retrieved from https://www.youtube.com/watch?v=XNtdnPjRpzI. Accessed on 11 November 2022.

Curry, E., Dustdar, S., Sheng, Q. Z., & Sheth, A. (2016). Smart cities-enabling services and applications. doi:10.1186/s13174-016-0048-6

Dadwal, S. S., Jamal, A., Harris, T., Brown, G., & Raudhah, S. (2019). Technology and sharing economy-based business models for marketing to connected consumers. In S. Dadwal (Ed.), *Technology and sharing economy-based business models for the connected consumers* (1st ed., pp. 62–93). Hershey, PA: IGI Global. doi:10.4018/978-1-7998-0131-3.CH004

DeBono, E. (2019). Six thinking hats – De Bono Group. Retrieved from https://www.debonogroup.com/services/core-programs/six-thinking-hats/. Accessed on 11 November 2022.

Dener, M. (2019). The role of cloud computing in smart cities. *Technology, Engineering & Mathematics (EPSTEM)*, *7*, 39–43. Retrieved from www.isres.org. Accessed on 10 November 2022.

Deolite. (2022). Episode #27: Is technology our planet's best hope? | Deloitte UK. Retrieved from https://www2.deloitte.com/uk/en/pages/about-deloitte-uk/articles/the-green-room-podcast-is-technology-our-planets-best-hope.html?utm_source=googlead&utm_medium=paid-owned&utm_id=GreenRoomPodcast-episode27&utm_content=text&gclid=CjwKCAjwyryUBhBSEiwAGN5OCLc. Accessed on 26 May 2022.

DoT Govt of India. (2019). *Technical Report- IoT/ICT enablement in smart cities – Design and planning of smart cities*. Retrieved from https://www.tec.gov.in/pdf/M2M/Design. Planning Smart Cities with IoT ICT.pdf. Accessed on 30 October 2022.

Fu, Y., Jia, S., & Hao, J. (2015). A scalable cloud for Internet of Things in smart cities. *Journal of Computers*, *26*(3). Retrieved from http://csroc.org.tw/journal/JOC26_3/JOC26_3_7.pdf. Accessed on 10 November 2022.

Hamza, M. (2021). These are the top 20 sustainable smart cities in the world, disruptive technologies. Retrieved from https://www.disruptive-technologies.com/blog/the-top-20-sustainable-smart-cities-in-the-world. Accessed on 26 May 2022.

Harmon, R. R., Castro-Leon, E. G., & Bhide, S. (2015). Smart cities and the Internet of Things. In *Portland International Conference on Management of Engineering and Technology* (pp. 485–494). Portland State University. doi:10.1109/PICMET.2015.7273174. 2015-Septe.

Hofstede, G., et al. (1997). *Cultures and organizations. Software of the mind*. New York, NY: McGraw-Hill.

Höjer, M., & Wangel, J. (2014). Smart sustainable cities: Definition and challenges. In *Advances in intelligent systems and computing* (pp. 333–349). Retrieved from https://www.academia.edu/24953067/Smart_Sustainable_Cities_Definition_and_Challenges. Accessed on 11 November 2022.

HPE. (2022). What is infrastructure as a service (IaaS)? | Glossary | HPE EUROPE. Retrieved from https://www.hpe.com/emea_europe/en/what-is/infrastructure-as-a-service.html. Accessed on 10 November 2022.

Iberdrola. (2021). Blockchain for smart cities: The future of urban management – Iberdrola. Retrieved from https://www.iberdrola.com/innovation/blockchain-for-smart-cities-urban-management. Accessed on 13 November 2022.

Ismagilova, E., Hughes, L., Dwivedi, Y. K., & Raman, K. R. (2019). Smart cities: Advances in research—An information systems perspective. *International Journal of Information Management*, *47*, 88–100. doi:10.1016/J.IJINFOMGT.2019.01.004. Elsevier Ltd.

Kakderi, C., Tsarchopoulos, P., Komninos, N., Panori, A., Kakderi, C., Tsarchopoulos, Á. P., Panori, Á. A., Tsarchopoulos, P., Panori, A., & Komninos, N. (2019). Smart cities on the cloud. In A. Stratigea & D. Kavroudakis (Eds.), *Mediterranean cities and Island communities* (1st ed.). Springer Nature Switzerland. doi:10.1007/978-3-319-99444-4_3

Kakderi, C., Komninos, N., & Tsarchopoulos, P. (2016a). Smart cities and cloud computing: Lessons from the STORM CLOUDS experiment. *Journal of Smart Cities*, *2*(1). doi:10.18063/JSC.2016.01.002. Whioce Publishing Pte Ltd.

Kakderi, C., Komninos, N., & Tsarchopoulos, P. (2016b). Smart cities and cloud computing introduction to the special issue. *Journal of Smart Cities*, *2*(1). doi:10.18063/JSC.2016.01.001. Whioce Publishing Pte Ltd.

Khan, Z., Anjum, A., Soomro, K., & Tahir, M. A. (2011). Performance analysis of OFDM modulation on indoor broadband PLC channels. *Journal of Cloud Computing: Advances, Systems and Applications*, *4*(2). doi:10.1186/s13677-015-0026-8

Maheswar, R., Balasaraswathi, M., Rastogi, R., Sampathkumar, A., & Kanagachidambaresan, G. R. (2021). *Challenges and solutions for sustainable smart city development*. In R. Maheswar, M. Balasaraswathi, R. Rastogi, A. Sampathkumar, & G. R. Kanagachidambaresan (Eds.). Springer. doi:10.1007/978-3-030-70183-3

Nouh, R. M., & Singh, D. (2020). *Introducing blockchain for smart city technologies and applications*. Springer. doi:10.1007/978-981-15-2205-5_1

Nowicka, K. (2014). Smart city logistics on cloud computing. In *1st International Conference Green Cities 2014 – Green Logistic*. Social and Behavioral Sciences Science Direct. Retrieved from https://pdf.sciencedirectassets.com/277811/1-s2.0-S1877042814X00509/1-s2.0-S1877042814054676/main.pdf?X-Amz-Security-Token=IQoJb3JpZ2luX2VjEH8aCXVzLWVhc3QtMSJHMEUCIArwf4LidzeBAuK4RupcRH2iD7hzfOI5KiQ%2FE0UsTKjnAiEA2PBtIDaROhqsK2sOAoo8BW6JgsUMnVhJAmlMYfn%2F. Accessed on 10 November 2022.

Olofsson, L., & Farr, R. (2006, July). Business model tools and definition. *Business*, p. 31. Retrieved from https://www.researchgate.net/publication/272813909_Business_Model_Tools_and_Definition_-_a_Literature_Review

Salha, R. A., El-Hallaq, M. A., & Alastal, A. I. (2019). Blockchain in smart cities: Exploring possibilities in terms of opportunities and challenges. *Journal of Data Analysis and Information Processing*, *7*(3), 118–139. doi:10.4236/JDAIP.2019.73008. Scientific Research Publishing.

Shetty, N., Renukappa, S., Subashini, S., & Khaled, A. (2019). Smart city business models – A systematic literature review. In *3rd International Conference on Smart*

Grid and Smart Cities 2019, June 25–28, 2019 | University of California, Berkeley, USA. Berkeley: University of California. Retrieved from https://wlv.openrepository.com/bitstream/handle/2436/622944/SC_BM_Shetty%20etal.pdf?sequence=3&isAllowed=y. Accessed on 11 November 2022.

Songhorabadi, M., Rahimi, M., Mahdi, A., Farid, M., & Kashani, M. H. (2016). Fog computing approaches in smart cities: A state-of-the-art review. IEEE.

Srinivasan, R. (2020). Internet of Things in smart cities. Retrieved from https://www.wfeo.org/wp-content/uploads/stc-information/L2-IoT_in_Smart_Cities-By-R_Srinivasan.pdf. Accessed on 28 October 2022.

Thales. (2021). What is a smart city? Technology and examples. Retrieved from https://www.thalesgroup.com/en/markets/digital-identity-and-security/iot/inspired/smart-cities. Accessed on 10 November 2022.

Toli, A. M., & Murtagh, N. (2020). The concept of sustainability in smart city definitions. *Frontiers in Built Environment*, *6*. doi:10.3389/FBUIL.2020.00077/FULL. Frontiers Media S.A.

UNECE and ITU. (2021). Sustainable smart cities | UNECE. Retrieved from https://unece.org/housing/sustainable-smart-cities. Accessed on 26 May 2022.

Verma, A. (2017). Smart city business model: Revenue potential of existing assets – Buro Happold, Buro Happod. Retrieved from https://www.burohappold.com/news/smart-city-business-model-revenue-potential-existing-assets/#. Accessed on 11 November 2022.

Wocomodocs. (2015). Smart cities – Building for the cities of tomorrow (documentary, 2015) – YouTube. Retrieved from https://www.youtube.com/watch?v=svvIHxwgmDY. Accessed on 11 November 2022.