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What Is Smart City?

1.1 Introduction

One of the reasons behind the lack of unified definitions of a smart city is because of the various entities involved and the functions the smart city provides. Hence, existing definitions can vary greatly. There are several definitions for a smart city which are defined by various organizations and stakeholders.

The most common consensus is that the smart city employs various kinds of digital and electronic technologies to transform the living environments with Information and Communications Technologies (ICTs) [1, 2]. Deakin [3] labeled the smart city as a city that employs ICT to meet the market (the citizens') needs. There is a need for larger community involvement to achieve a smart city. A smart city does not simply contain ICT technology but has also developed the technology to achieve positive impacts to the local community. Some definitions for a smart city from major professional organizations and government agencies are given as follows:

Association of Southeast Asian Nations [4]: "A smart city in ASEAN harnesses technological and digital solutions as well as innovative non-technological means to address urban challenges, continuously improving people's lives and creating new opportunities. A smart city is also equivalent to a 'smart sustainable city,' promoting economic and social development alongside environmental protection through effective mechanisms to meet the current and future challenges of its people, while leaving no one behind. As a city's nature remains an important foundation of its economic development and competitive advantage, smart city development should also be designed in accordance with its natural characteristics and potentials."

British Standard Institution [5]: A smart city is an "effective integration of physical, digital, and human systems in the built environment to deliver a sustainable, prosperous, and inclusive future for its citizens."

Department for Business, Innovation, and Skills, UK [6]: "A Smart City should enable every citizen to engage with all the services on offer, public as well as private, in a way best suited to his or her needs. It brings together hard infrastructure, social capital including local skills and community institutions, and (digital) technologies to fuel sustainable economic development and provide an attractive environment for all."

European Commission [7]: "A smart city is a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business. A smart city goes beyond the use of ICT for better resource use and less emissions. It means smarter urban transport networks, upgraded water supply and waste disposal

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facilities and more efficient ways to light and heat buildings. It also means a more interactive and responsive city administration, safer public spaces and meeting the needs of an ageing population."

Innovation and Technology Bureau, Hong Kong [8]: "Embrace innovation and technology to build a world-famed Smart Hong Kong characterized by a strong economy and high quality of living."

Institute of Electrical and Electronics Engineers Smart Cities Community [9]: A smart city gathers government, technology, and society to achieve a minimum of the following factors: smart mobility, a smart economy, a smart environment, smart cities, smart governance, smart people, and smart living.

International Electrotechnical Commission [10]: "A smart city is one where the individual city systems are managed in a more integrated and coherent way, through the use of new technologies and specifically through the increasing availability of data and the way that this can provide solid evidence for good decision making."

Japan Smart Community Alliance [11]: The expression "Smart Community" is more widespread than "Smart City" in Japan [7]. "A smart community is a community where various next-generation technologies and advanced social systems are effectively integrated and utilized, including the efficient use of energy, utilization of heat and unused energy sources, improvement of local transportation systems and transformation of the everyday lives of citizens."

Ministry of Housing and Urban Affairs, India [12]: "The conceptualization of Smart City, therefore, varies from city to city and country to country, depending on the level of development, willingness to change and reform, resources and aspirations of the city residents. A smart city would have a different connotation in India than, say, Europe. Even in India, there is no one way of defining a smart city."

According to the above, the similarity and differences in smart city definitions can be summarized as follows:

- Similarities:
  - Enhancement of living standards by making informed decisions with advanced technologies to collect, process, and evaluate data.
  - Systems are integrated to exchange information.
  - Citizens are better informed about their surroundings.
  - Sustainability and environmental conservation should be maximized.
- Differences:
  - Smart city domains or elements, e.g. transport, energy, and health (explained in the following section), can be different due to regional interests.

From the above summary, it is shown that for a city to become smart, multiple sources of data from a range of urban activities and domains must be connected to reveal opportunities to bring innovation to today's connected citizens. Deloitte [13] stated that a smart city is driven by the innovation success of six key domains including:

1) Energy and environment: sustainable growth is created by technology and cities make better use of resources from electronic sensors that monitor leakages, as well as gamification and behavioral economics to support citizens to conduct considerate decisions on resource utilization [14]. Renewable energy including solar and wind will be important sources of energy generation [15–17]. Data analytics will be used to enhance energy and power system operation [18].

2) Economy: the economy will be affected by digitization and disruptive technologies, which will change the needs of several types of jobs. Smart cities need to create strategies to adopt future jobs that will power Industry 4.0 and beyond [19].
3) Safety and security: as criminals will make use of technology to commit advanced crimes, public safety and security authorities will also use technology for crime prevention by assessing multiple streams of social and crowdsourced information, including super-resolution images [20] and image fusion [21].
4) Health and living: the lives of citizens are enhanced with technology and connectivity. Connected communities are achieved with smart buildings. Enhanced social programs and innovated health care sector are data-driven [22].
5) Mobility: the integrated mobility systems include autonomous vehicles and shared mobility services achieved with the Internet of Things (IoT). The concept of IoT occurs when devices are communicating with other devices on behalf of people and will dominate the future of Internet communications [23]. Advanced analytics allow citizens and goods to travel in ways that are safer, cheaper, cleaner, and faster [24].
6) Education and government: technological advancement will aid government procedures and give a seamless experience to businesses. Smart cities use analytics to assist authorities to create insight-driven policies, monitor performance and outcomes, allow constituent engagement, and enhance government efficiency. Data and analytics will also assist next-generation teachers to familiarize their counseling and teaching for greater student achievement. More creative and personalized education plans can be created such as virtual learning environments [25].

Similarly, Giffinger et al. [26] described the smart city as having six domains, including:

1) Smart economy: consists of features surrounding economic competitiveness including entrepreneurship, innovation, flexibility, the productivity of the labor market, trademarks, and participation in the global market.
2) Smart people: concerns not only the level of qualification or education received by citizens but also additional social interactions and perceptions of public life.
3) Smart governance: concerns political involvement, citizen services, and administration functions.
4) Smart mobility: includes local and global accessibility with the presence of ICTs and sustainable and relevant transport systems.
5) Smart environment: concerns attractive natural conditions including green space, less extreme climate, reduced pollution, resource management, and working to achieve environmental protections.
6) Smart living: includes many features of quality of life composed of health, housing, culture, tourism, and safety.

It is worth noting that there are other domains apart from smart energy, smart transportation and smart health (to be discussed further later), including:

Smart water [27, 28]: Smart water systems employ IoT-enabled sensors to collate real-time data. With precise and reliable data, smart water systems can drive great transformations in water sector transparency and accountability. There will be governance improvements, risk reductions, water quality control, and eventually novel business cases for water sector investment [28]. The data allows water facilities optimization by detecting leaks or observing how water is distributed in the water network. The optimization model empowers citizens to make better decisions about water management. Smart sensors can detect water pipe leaks and quickly inform engineers to take action and resolve the issue. Smart water is critical as an estimated 3.3 billion liters of water is wasted daily in Wales and England due to leaks in water networks [27].

Smart waste [29, 30]: Interreg Europe [30] described smart waste as being used "to improve public policy instruments supporting innovation within waste management procedures. The final result? Smarter, more effective, sustainable, and cost-efficient waste management, benefiting all territorial stakeholders." In the United Kingdom, illegal waste activity including fly-tipping costs the UK economy approximately £600 M annually [29]. The present systems for monitoring commercial and household waste are out-of-date and mainly paper based. Smart waste employs technology including blockchain [31], electronic chips, and sensors for monitoring waste, waste containers, and waste vehicles. Smart waste is an element of smart living and smart environments.

In summary, a smart city is an ambitious and crucial transformation of many cities worldwide. Benefits including improved living conditions are reaped from several sectors/domains. However, a smart city consists of the development and application of novel technologies. There is a need for standardized uniform engineering or technical criteria, methods, processes, and practices. The next section examines how international standards help to build a smart city.

1.2 Characteristics, Functions, and Applications

1.2.1 Sensors and Intelligent Electronic Devices

A sensor is a device aiming to detect events or changes in its environment and send the information to other electronic modules. It responds to a stimulus, such as heat, light, or pressure, and generates a signal that can be measured.

A good sensor must have the features sensitive to the measured property, but insensitive to any other property likely to be encountered in its application, and it will not influence the measured property.

Sensors are used in everyday objects such as touch-sensitive lamps which dim or brighten by touching. With the advancement in industry, the use of sensors has expanded beyond temperature, pressure, or flow measurement. Applications include vehicles, manufacturing, machinery, airplanes, medicine, and many other areas of our day-to-day life. There are a wide range of other sensors, measuring chemical and physical properties of materials. Some examples consist of optical sensors for refractive index measurement, vibrational sensors for fluid viscosity measurement and electro-chemical sensor for monitoring pH of fluids.

A sensor's sensitivity indicates how much the sensor's output changes when the input quantity being measured changes. For instance, if the mercury in a thermometer moves 1 cm when the temperature changes by 1 °C, the sensitivity is 1 cm/°C by assuming there is a linear relationship. Some sensors can also be affected what they measure, namely, a room temperature thermometer inserted into a hot cup of liquid cools the liquid while the liquid heats the thermometer. Sensors are usually designed to have a small effect on what is measured; therefore by making the sensor smaller can often improve accuracy and introduce other advantages, for example, convenience in installation.

Technological progress allows more and more sensors to be manufactured such as microsensors which can have a significantly faster measurement time and higher sensitivity compared with macroscopic approaches. Due to the increasing demand for rapid, affordable, and reliable information, low-cost and easy-to-use devices for short-term monitoring or single-shot measurements have gained growing importance. Using this class of disposal sensors, critical analytical information can be obtained by anyone, anywhere, and at any time, without the need for recalibration and worrying about contamination.

Monitoring sensors are used for house monitoring, office, and agriculture monitoring. Traffic monitoring includes car speed, traffic jams, and traffic accidents; weather monitoring is for rain, wind, lightning, and storms; defense monitoring is for monitoring temperature, humidity, air pollution, fire, health, security, and lighting. Some sensors are used to detect carbon monoxide, sulfur dioxide, hydrogen sulfide, ammonia, and other gas substances. Sensors include intelligent sensors and wireless sensor network (WSN) technology.

The intelligent sensor can give a digital signal, communicate the signal, and execute logical instructions. To qualify as an intelligent sensor, the sensor must be part of the same physical unit. A sensor whose only function is to detect and send an unprocessed signal to an external system which performs some action is not considered intelligent.

Common types of intelligent electronic devices (IEDs) include protective relaying devices, circuit breaker controllers, capacitor bank switches, and recloser controllers. A typical IED can contain several protection functions, control functions controlling separate devices, an auto-reclose function, self-monitoring function, and communication functions. Some recent IEDs are designed to support the IEC61850 standard for substation automation, which provides interoperability and advanced communications capabilities.

1.2.2 Information Technology, Communication Networks, and Cyber Security

Information technology is the development, maintenance, or use of systems, especially computer systems, software, and networks for storing, retrieving, and sending information. Computer networking is the process of electronically linking computing devices to exchange information through data connections.

Communication Networks can be of the following five types: local area network (LAN), metropolitan area network (MAN), wide area network (WAN), wireless, and inter network (Internet).

LAN is designed for small physical areas such as an office, group of buildings, or a factory. LANs are used widely as it is easy to design. Personal computers and workstations are connected to each other through LANs. Different types of topologies such as star, ring, bus, and tree could be used. LAN can be a simple network like connecting two computers, to share files, resources such as printers, shared hard-drive, and network among each other while it can also be as complex as interconnecting an entire building.

MAN was developed in the 1980s. It is basically a bigger version of LAN. It is designed to extend over the entire city. It is mainly operated by a single private or public company. MAN generally covers towns and cities of 50 km. The communication medium used for MAN are in general optical fibers and cables.

WAN can be private or it can be public leased network. It is used for the network that covers large distance such as cover states of a country. It is not easy to design and maintain. WAN generally covers large distances between states, countries, or continents. Communication medium used are satellite and public telephone networks which are connected by routers.

Wireless networks can be divided into three main categories, namely, System interconnection, wireless LANs, and wireless WANs.

System interconnection is all about interconnecting the components of a computer using short-range radio. Some companies design a short-range wireless network called Bluetooth to connect various components such as monitor, keyboard, mouse, digital cameras, headsets, scanners, and printer, to the main unit, without wires.

Inter network or Internet is a combination of two or more networks. Inter network can be formed by joining two or more individual networks by means of various devices such as routers, gateways, and bridges.

Cyber security is the practice of defending computers, servers, mobile devices, electronic systems, networks, and data from malicious attacks. It is also known as information technology security.

1.2.3 Systems Integration

System integration is the process of integrating all the physical and virtual components of an organization's system. In engineering, it is the process of bringing together the component subsystems into one system. The physical components consist of the various machine systems and computer hardware. The virtual components consist of data stored in databases, software, and applications. An aggregation of subsystems cooperates so that the system is able to deliver the overall functionality.

In general, there are six steps in systems integration process that is, requirements gathering, analysis, architecture design, systems integration design, implementation, and maintenance. The main reason for businesses to use system integration is the growing need to improve productivity and quality of day-to-day operations. The goal is to get organization and business IT systems to communicate with each other through integration. This accelerates information outflow and reduces operational costs and improves efficiency.

Before integrating systems, usually, the organizations need to rekey the same information into multiple systems. This makes the flow of information within the organization very slow. One of the main benefits of system integration is after automatically integrating systems, the automated exchange of information will make the information consistent between disparate systems. Critical information is more quickly available throughout the organizations. This allows for faster and better decision-making.

1.2.4 Intelligence and Data Analytics

Data analytics help the business users to analyze historical and present data, thereby predicting future trends and change the proposed business model. This helps businesses optimize their performances. Implementing it into the business model means organizations can help reduce costs by identifying more efficient ways of doing business, making decision, and by storing large amounts of data.

Therefore, data analytic techniques enable the users to take raw data and uncover patterns to extract valuable insights from it. Today, many data analytics techniques use specialized systems and software that integrate artificial intelligent algorithms and automation.

When strategizing for something as comprehensive as data analytics, including solutions across different facets is necessary. Depending on the stage of the workflow and the requirement of data analysis, there are four main kinds of analytics, namely, descriptive, diagnostic, predictive, and prescriptive.

Turning to big data analytics, this helps businesses to get insights from huge data resources. People, organizations, and devices now produce massive amounts of data. Social media, cloud applications, and machine sensor data are some examples.

1.2.5 Management and Control Platforms

A management control system (MCS) gathers and uses information to evaluate the performance of different organizational resources such as human, physical, financial, and also the organization as a whole in respect to the organizational strategies followed.

One MCS characteristic is the organizing and planning of the relationship between these different structures and centers of responsibility. The other characteristic is about the processes or set of activities the organization takes in order to achieve its aims.

1.3 Smart Energy

Smart energy is the process of adopting intelligent devices such as smart sensors for increasing energy efficiency. It focuses on large-scale sustainable renewable energy sources that promote greater eco-friendliness while reducing costs and increasing reliability. To accommodate for ever-increasing data, the application of smart devices to human lifestyles and services, secure computer systems that meet the needs of smart cities are essential. This includes new architecture, concepts, algorithms in machine learning, and artificial intelligence. Smart energy networks require fast and intelligent decisions, which will only be possible with the help of intelligent and complex computer systems. Urban energy networks are becoming increasingly linked and integrated. This is crucial for cities aiming to achieve energy efficiency and environmental sustainability.

There are ongoing advances in renewables and energy storage systems, along with innovative information, communication and control technologies, computational intelligence, as well as power electronics. Thus, there are opportunities and challenges emerging in the design, planning, and operation of more distributed energy system architectures with a significant amount of local energy consumptions [32]. The enabling technologies and methodologies aimed at addressing complex challenges include decentralized computing, self-organizing sensor networks, proactive control, and holistic computing frameworks [18].

The development of smart grids has given various challenges facing on power system operation and planning due to increased penetration of many new technologies of diversified properties. On one hand, system operators and many other participants have to deal with increased uncertainties and risks involved in daily operation and planning activities. On the other hand, applications of many new metering and measurement devices, capable of closely monitoring and sensing grid operation in real time, result in overwhelming amount of measurement data of high precision and resolution. By far, how to make the best use of the massive data remains quite a challenging task facing power system researchers and practitioners. The availability of the high-quality data could potentially facilitate risk hedging and decision-making in system operation and planning, of which the prerequisite calls for innovative informatics approaches that are intelligent, data-driven, and capable of handling various complex problems. Zhao et al. [33] reported some recent work done in some areas related to smart energy. For instance, the application of advanced data mining techniques has enabled better prognosis of renewable generations that are highly uncertain and intermittent. Specially, a revolutionary change of forecasting paradigm moving from the point-based forecasting approaches toward the probabilistic interval-based ones by utilizing advanced data analytic techniques such as extreme learning machine to achieve better prognosis and representation of the uncertainties and intermittencies involved in renewable energies. The wide area measurement systems data measured by widely deployed phasor measurement units has been exploited to develop advanced online power system security surveillance and visualization tools by many power utilities. There are also industrial applications of intelligent and data-oriented approaches dedicated for resolving complex control and operation problems in transmission or distribution grids with high renewable energy penetration. In terms of electricity market operation, applications of advanced data analytic techniques have been popular to construct optimal bidding strategies for generators or electric vehicle aggregators, as well as short load forecasting and electricity market price forecasting. There are also many applications of risk-based techniques to counterbalance the uncertainties facing construction/expansion planning, as well as operation planning in context of deregulated electricity markets.

Since solar resource is intermittent and noncontrollable which depends on the location, time of day, day of year, and weather pattern, the difficulty of short-term solar irradiance forecasting lies in challenges to predict variations of weather patterns and quantify their impacts. Approaches including numerical weather prediction models, image-based models, statistical models, machine learning models, and hybrid models for solar irradiance forecasting have been widely discussed [15].

Huang et al. [34] reported the study of short-term forecasting of solar irradiance at a targeted site with consideration of its time series and measurements at neighboring sites. A data-driven framework for forecasting solar irradiance based on fusing spatial and temporal information was proposed. In the framework, data-driven approaches including boosted regression trees (BRTs), artificial neural network (NN), support vector machine, and least absolute shrinkage and selection operator are applied to model spatial dependence among solar irradiance time series thereby to generate forecasts of solar irradiance at the targeted site. Bench marking models including scaled persistence model, auto regressive model, and auto regressive exogenous model are employed to further validate the effectiveness of data-driven forecasting models. Computational results of multiple steps ahead forecasting demonstrate that the BRT model gives the best performance with the lowest normalized root mean squared error for forecasting horizons up to two hours.

Regarding day-ahead power market (DAM), load serving entities (LSEs) are required to submit their future load schedule to market operator. As a more accurate load forecasting model may not lead to a lower cost for LSEs, accurate pursuing load forecast model may not target a solution with optimal benefit. Facing this issue, Xu et al. [35] initiated a beneficial correlated regularization (BCR) for neural network (NN) load prediction. The training target of NN contains both accuracy and power cost consideration. The result shows that NN with BCR can reduce power cost with acceptable accuracy level.

There are two major ways to make energy more sustainable, namely, using renewable energy such as solar, wind, geothermal, and improving energy utilization efficiency. The generation of renewable energy is still not very stable and scalable in comparison to traditional energy generation methods, e.g. coal and nuclear power plants. With the fact that 40% of global energy is consumed by residential and commercial buildings, effective management of the energy usage is essential to improve energy efficiency. Load monitoring has great potential in many useful applications, for examples, energy awareness and energy conservation, controllable load quantitative evaluation, human behavior, and load prediction. Load monitoring helps to understand the energy consumption of specific appliances in a house and make a more energy efficient plan. If the electricity customers are aware of the average consumption of a type of appliance, more personalized and specific energy saving models of appliances can be recommended to those who are using inefficient devices.

Current methods for nonintrusive load monitoring (NILM) problems assume that the number of appliances in the target location is known which may be unrealistic. In the real-world, the initial settings of the site can be known, but new appliances can be added by the user after a period of time, especially in a household. Zhang et al. [36] proposed an appliance detection and a training algorithm for multi-label classification in NILM. Then the Stochastic Sensitivity Measure-based Noise

Filtering and Oversampling (SSMNFOS) is applied to train base classifier for an appliance to form the multi-class ensemble of NN for the multi-label classification. Experimental results show that the SSMNFOS yields a better performance than the widely used SMOTE (Synthetic Minority Oversampling Technique); the SSMNFOS is more robust to noisy samples. This is important to the NILM problem because the load measured by the smart meter may have noise interference from wires and the environment.

Wu et al. [37] presented a probabilistic prediction interval (PI) model based on variational mode decomposition (VMD) and a kernel extreme learning machine using the firefly algorithm (FA-KELM) to tackle the problem of photovoltaic (PV) power for intra-day-ahead prediction. First, considering the nonstationary and nonlinear characteristics of a PV power output sequence, the decomposition of the original PV power output series is carried out using VMD. Second, to further improve the prediction accuracy, KELM is established for each decomposed component and the firefly algorithm is introduced to optimize the penalty factor and kernel parameter. Finally, the point predicted value is obtained through the summation of predicted results of each component and then using the nonlinear kernel density estimation to fit it. The cubic spline interpolation algorithm is applied to obtain the shortest confidence interval. Results from practical cases show that this probabilistic prediction interval could achieve higher accuracy as compared with other prediction models.

As load forecasting is a complex nonlinear problem with high volatility and uncertainty, Lai et al. [38] reported a novel load forecasting method known as deep neural network and historical data augmentation (DNN–HDA). The method utilizes HDA to enhance regression by DNN for monthly load forecasting, considering that the historical data to have a high correlation with the corresponding predicted data. To make the best use of the historical data, one year's historical data is combined with the basic features to construct the input vector for a predicted load. In this way, if there is C years' historical data, one predicted load can have C input vectors to create the same number of samples. DNN–HDA increases the number of training samples and enhances the generalization of the model to reduce the forecasting error. The method is tested on daily peak loads from 2006 to 2015 of Austria, Czech, and Italy. Comparisons are made between DNN-HDA and several state-of-the-art models. DNN–HDA outperforms DNN by 60%.

Accurate load forecasting is essential to the operation and planning of power systems and electricity markets. Lai et al. [39] proposed an ensemble of radial basis function neural networks (RBFNNs) for short-term and mid-term load forecasting. Exogenous features and features extracted from load series with long short-term memory networks and multi-resolution wavelet transform in various timescales are used to train the ensemble of RBFNNs. Multiple RBFNNs are fused as an ensemble model with high generalization capability using a proposed weighted fusion method based on the localized generalization error model. Experimental results on three practical datasets show that compared with other forecasting methods, the proposed method reduces the mean absolute percentage error (MAPE), mean squared error (MSE), and mean absolute error (MAE) by up to 0.30%.

Wang et al. [40] also reported a short-term electric load forecasting model based on deep autoencoder with localized stochastic sensitivity (D-LiSSA). D-LiSSA can learn informative hidden representations from unseen samples by minimizing the perturbed error (including the training error and stochastic sensitivity) from historical load data. Specifically, this general deep autoencoder network as a deep learning model improves prediction accuracy and reliability. Moreover, a nonlinear fully connected feedforward NN as a regression layer is applied to forecast the short-term load, with the generalization capability of the proposed model using hidden representations learned by D-LiSSA. The performance of D-LiSSA is evaluated using real-world public electric load markets of France (FR), Germany (GR), Romania (RO), and Spain (ES) from ENTSO-E. Extensive experimental results and comparisons with the classical and state-of-the-art models show that D-LiSSA yields accurate load forecasting results and achieves desired reliable capability. For instance, with the French case, D-LiSSA yields the lowest mean absolute error, mean absolute percentage error, and root mean squared error; providing up to 63% forecasting accuracy improvements as compared to the benchmark model for forecasting hourly horizon.

Solar radiation forecasting is a key technology to improve the control and scheduling performance of photovoltaic power plants. Lai et al. [41] proposed a deep learning-based hybrid method for one-hour ahead Global Horizontal Irradiance (GHI) forecasting. Specifically, a deep learning-based clustering method, deep time-series clustering, is adopted to group the GHI time series data into multiple clusters to better identify its irregular patterns and thus providing a better clustering performance. Then, the feature attention deep forecasting (FADF) DNN is built for each cluster to generate the GHI forecasts. The developed FADF dynamically allocates different importance to different features and utilizes the weighted features to forecast the next hour GHI. The solar forecasting performance of the proposed method is evaluated with the National Solar Radiation Database. Simulation results show that the proposed method yields the most accurate solar forecasting among the smart persistence and state-of-the-art models. The proposed method reduces the root mean square error as compared to the smart persistence by up to 13%.

Large-scale deployment of wind energy is constrained by the inherent intermittence and volatility. Therefore, an accurate prediction of wind power is needed. Yin et al. [42] reported a hybrid forecasting model for the short-term wind power prediction by using a secondary hybrid decomposition approach to decompose the original time series into several intrinsic mode functions. The proposed approach has great advantage over other previous hybrid models in terms of prediction accuracy.

With the increasing penetration of wind power in renewable energy systems, it is important to improve the accuracy of wind speed prediction. However, wind power generation has great uncertainties which make high-quality interval prediction a challenge. Existing multi-objective optimization interval prediction methods do not consider the robustness of the model. Thus, trained models for wind speed interval prediction may not be optimal for future predictions. Chen et al. [43] proposed the prediction interval coverage probability, the prediction interval average width, and the robustness of the model used as three objective functions for determining the optimal model of short-term wind speed interval prediction using the multi-objective optimization. Furthermore, a new Stochastic Sensitivity for Prediction Intervals (SS_PIs) was proposed to measure the stability and robustness of the model for interval prediction. Using wind farm data from countries on two different continents as case studies, experimental results show that the proposed method yields better prediction intervals than other methods under different confidence levels. In terms of the SS_PIs.

The satisfactory operating condition and performance of transformers are essential for a reliable power grid operation. The condition diagnosis and monitoring of oil/paper systems in the transformer are thus of great interest to engineers and researchers. The dissolved gas analysis (DGA) is generally considered to be the most convenient and common approach for reconditioning the energized transformers. Since the diagnostic accuracy of the traditional DGA can no longer meet the requirements of modern power grids, the artificial intelligence (AI) diagnostic algorithm based on DGA has become a prevailing method for the fault diagnosis of the oil/paper system in power transformers [44].

Moisture is one of the critical factors to determine the service life of transformers. The moisture inside the transformer oil-immersed insulation could be quantified with feature parameters.

Liu et al. [45] proposed and developed a genetic algorithm support vector machine (GA-SVM) model to carry out the moisture diagnosis. The finding revealed that these feature parameters can be obtained by using frequency-domain spectroscopy. Therefore, a novel model for predicting the frequency-domain spectroscopy curves is first reported based on a small number of samples, which could be utilized to obtain the feature parameters data base to develop GA-SVM. The model is under exploration as an intelligent based moisture diagnosis tool for power transformers.

Some of the benefits derived from smart energy technology such as a more diverse power supply, a reduction in air pollution and emissions that cause global warming and a growing independence from traditional energy sources that harm the environment. In brief, the move toward smart energy is one that will create a brighter, eco-friendlier future. With global warming and other climate issues currently a major policy concern for governments globally, the switch to smart energy is becoming more important than ever before.

1.4 Smart Transportation

Smart transportation system is the application of sensing, analysis, control, and communications technologies to transportation to improve safety, mobility, and efficiency. Smart transportation system includes a wide range of applications that process and share information to ease congestion, improve traffic management, and minimize environmental impact.

Smart transportation includes the use of several technologies, from basic management systems such as car navigation, traffic signal control systems, container management systems, automatic number plate recognition, or speed cameras to monitor applications, such as security CCTV systems, and to more advanced applications. The use of IoT-enabled technology is changing the way that the transportation sector operates. A smart transportation network is clean and efficient. As suggested, reduced traffic congestion results in cleaner air, less wasted time, and reduced energy consumption. And cities that are working to accommodate electric and, eventually, autonomous connected vehicles can expect to realize even greater environmental benefits. Smart transportation system gives regular information to the daily commuters about public buses, timings, seat availability, the current location of the bus, time taken to reach a particular destination, next location of the bus, and the density of passengers inside the bus. Therefore, advantages of smart transportation system include travel time improvement, capacity management, and incident management. There is a range of information and communications technologies that enables the development of smart transportation. For instance, fiber optics, GPS, laser sensors, digital map databases, and display technologies. Enabling technologies can be divided into the following several classes [46].

Data Acquisition:

To monitor traffics using several means such as traffic sensor. Examples of traffic sensors are ultrasonic and radar, video image detector (VID), and visual images from closed circuit television (CCTV) which provide live images to help the traffic center operator to monitor complicated traffic situations and make decisions.

1.4.1 Data Processing

Information collected at data management center required to be processed, verified, and consolidated into a format that is useful for the operators. This can be done using data fusion process. Automatic incident detection (AID) may also be used for data processing. Global positioning system (GPS) can be used on vehicles to process data.

Information Usage:

This involves controlling the flow of vehicles merging onto an expressway, and coordination of traffic control within large urban areas taking place at the traffic management center. In addition to dynamic route guidance which permits the user to make strategic decisions on minute interval, and adaptive cruise control which allows the driver to change vehicle speed to maximize safety.

1.5 Smart Health

The European Commission [47] described smart health permits healthcare providers to reduce illnesses occurrence, to care for patients more efficiently, and to cure illnesses more effectively. Smart health also reduces healthcare expenditure in the growing aging population. Smart health solutions consist of technological developments in portable and mobile devices, sensor technology, application development, mobile data connectivity, cloud computing, and big data analytics, with new ideas on patient comanagement, health tracking of remote neighborhoods, and minimizing unhealthy lifestyles. Deloitte [48] stated that smart health consists of five features, including to: (i) empower proactive health and well-being management to make choices that can proactively improve health, well-being, and quality of life to reduce adverse health outcomes in the future; (ii) foster a sense of community and well-being with virtual and in-person community meetings; (iii) enable digital technology and behavioral science with mobile applications for users to enter and track data and seek information, e.g. fitness tips and recipes, and deploy the use of coaching and guide to support adherence and uptake of behaviors associated with healthy, active living; (iv) meaningfully use data to improve outcomes and allow users to track their progress. Consent would be requested from users to share and use data, to enhance the program and for it to make improved recommendations; (v) enable new and innovative ecosystems to consist of the collaboration of businesses with all kinds of organizations, e.g. government agencies and academia to align on health outcome measures and coordinate on investments in communities.

1.6 Impact of COVID-19 Pandemic

Mobility behavior was impacted severely by the COVID-19 crisis. Crisis managers need access to credible and timely data; need to look at the potential of traffic management data for crisis management, list the different categories and types of traffic data sources and provide an overview of how policymakers, research institutions, and private companies can repurpose their data to monitor the effect of the crisis and the accompanying lockdown measures on mobility behavior [49].

Over the past couple of years, information gathered from connected travelers through smartphones and GNSS (Global Navigation Satellite System) trackers has become increasingly important for commercial purposes, research studies, and policy making. Aggregated mobility tracking data is an excellent source of information on people's transportation habits. While this data is already beneficial for general traffic management, these aggregated traffic flows are also invaluable to examine the impact of crisis-specific policies on population mobility patterns. Several commercial entities active in this domain have already published resources on how their datasets could be used to assess the impact of crises, such as the ongoing pandemic on urban mobility.

Connected vehicle technology enables cars, buses, trucks, and other infrastructure to sense their environment and communicate with each other. Data from connected vehicles can be useful in aggregated form. A large fraction of commercial cars and car-sharing companies have built-in location and activity trackers for fleet management. This data is useful to monitor real-time link speeds and to analyze changes in traffic intensity in certain areas during a crisis.

Data from Wi-Fi and Bluetooth scanners, which have been used previously for long-term monitoring of visitors to shops and touristic hot spots, can also be repurposed to monitor real-time business in shopping districts. Automated systems can use this information to send alerts to city officials, so that they can temporarily restrict access to certain areas to avoid overcrowding in times where social distancing is required.

Time-series information from ticketing machines in public parking garages and on-street parking zones can be a new source of information in crisis management. Unlike data from static vehicle counters, which merely convey information on traffic intensity, parking garage and on-street parking occupancy data can also inform crisis managers about trip destinations and trip purposes. The ticketing machines and parking garages typically have geographical coordinates attached to them, and these can be used as the actual destination of a car trip within the city.

The increasing popularity of shared cars, bicycles, and steps in European urban areas provides an additional opportunity for monitoring changes in mobility behavior in case of crises. These vehicles typically accommodate some forms of real-time location trackers. These location trackers, along with information on ticketing and reservations, are typically only used by the sharing companies for billing and fleet management. However, crisis managers can quickly repurpose it toward monitoring mobility, as the start and end locations, along with vehicle reservation times, can be used to build time-dependent transport modes. These can offer insight into when and where people are traveling.

As global communities respond to COVID-19, public health officials said that aggregated, anonymized products such as Google Maps could be helpful to make critical decisions.

The Community Mobility Report [50] aims to provide insights into what has changed in response to policies at combating COVID-19. The reports chart movement trends over time by geography, across different categories of places such as retail and recreation, groceries and pharmacies, parks, transit stations, workplaces, and residential. This can show how the community is moving around differently under COVID-19 [51].

In the reports, no personally identifiable information, like an individual's location, contacts, or movement, is made available at any point. Insights in these reports are created with aggregated, anonymized sets of data from users who have turned on the location history setting. These reports are powered by the world-class anonymization technologies that keep your activity data private and secure. These reports use differential privacy, which adds artificial noise to the datasets enabling high-quality results without identifying any individual person.

To monitor social distancing interventions, rather than showing individual travel or behavior patterns, information from multiple devices is aggregated in space and time, so that the data reflect an approximation of population-level mobility [52]. The estimates of aggregate flows of people are incredibly valuable. A map that examines the impact of social distancing messaging or policies on population mobility patterns will help county officials understand what kinds of messaging or policies are most effective. Comparing the public response to interventions, in terms of the rate of movement over an entire county from one day to the next.

1.7 Standards

1.7.1 International Standards for Smart City

The International Organization for Standardization (ISO) has described standards as "the first step towards the holy grail of an interoperable, plug-and-play world where cities can mix and match solutions from different vendors without fear of lock-in or obsolescence or dead-end initiatives" [53]. International standards are best practices created by global experts. Standards can be used to benchmark functional and technical performances. Standards make sure that technologies deployed in cities are efficient, safe, and well-integrated.

The largest and most well-established international standards organizations include ISO [54], the International Electrotechnical Commission (IEC) [55], and the International Telecommunication Union (ITU) [56] which were founded between 50 and 150 years ago. The description of these organizations are as follows:

- ISO is a nongovernmental and independent global organization with 164 national standards bodies as members. The standards body for each country (e.g. Bureau de Normalization (NBN) in Belgium and Ghana Standards Authority (GSA) in Ghana) works directly with ISO and aims to minimize diversity in technical definitions. ISO standards are applied in various fields including quality management, environmental management, IT security, energy management, health and safety, and food safety [54].
- IEC is the world's forefront organization for the groundwork and publication of international standards for electronic, electrical, and relevant technologies, i.e. "electrotechnology" [55]. IEC described technical and international standards as reflecting "agreements on the technical description of the characteristics to be fulfilled by the product, system, service or object in question. They are widely adopted at the regional or national level and are applied by manufacturers, trade organizations, purchasers, consumers, testing laboratories, governments, regulators and other interested parties." Standards help researchers, industry, regulators, and consumers globally to achieve an optimal experience and meet mutual needs for various countries. Standards establish one of the vital bases for the elimination of technical obstacles to trade.
- ITU is the United Nations bespoke agency for ICTs and enables global connectivity of communications networks [56]. ITU manages international satellite orbits and radio spectrum, creates the international standards that allow technologies and networks to be continuously interconnected, and aims to enhance ICT access for global communities.

The above organizations have developed standards to specify and establish definitions and methodologies for a set of smart cities indicators. For example, ISO 37122:2019 (Sustainable Cities and Communities – Indicators for Smart Cities) [54] intends to give a holistic set of indicators to evaluate advancement in developing a smart city. The standard includes multiple domains including education, energy, economy, environment and climate change, finance, governance, health, housing, population and social conditions, recreation, safety, solid waste, sport and culture, telecommunication, transportation, urban/local agriculture and food safety, urban planning, wastewater, and water. The World Council on City Data is a prominent initiative in using standardized city data to create smart cities [57]. The initiative hosts a network of innovative cities dedicated to refining quality of life and services with open city data and delivers a reliable and holistic platform for standardized urban metrics. The World Council on City Data is an international hub for international organizations, education partnerships across cities, corporate partners, and academia to expand innovation, envisage alternative futures, and construct enhanced cities. The initiative developed the first city data standards, namely, ISO 37120 (Sustainable development of communities: Indicators for city services and quality of life).

The IEC has identified over 1800 standards that already impact smart cities [58]. The SyC Smart cities promote the coordination of standards efforts of several IEC committees and other organizations, including ISO, to promote the development of standards to achieve integration, interoperability, and effectiveness of city systems. SyC Smart City is presently developing IEC 63152 as the best practice tool for city planners. Considering the higher frequency of natural disasters and destruction in some urban areas, IEC 63152 proposes guidelines to sustain several city services after a disruption occurs. IEC 63152 provides the fundamental concepts of how several city services can cooperate to uphold the supply of electricity.

ITU established Study Group 20 and United for Smart Sustainable Cities to develop standard activities in supporting the utilization of ICTs in a smart city [59]. These standards focus on terminologies for the IoT and smart cities, high-performing ICT infrastructures requirements, and the interoperability between various ICT or IoT networks. The ICT standard consists of four layers, namely the "application and support layer," "data layer," "communication layer," and "sensing layer."

In addition to the above three organizations, the Institute of Electrical and Electronics Engineers (IEEE) also develops international standards for smart cities. One of the most well-known IEEE standards is the IEEE 802 family, which was established in the early 1980s and covers LANs and MANs [60]. In recent years, IEEE has established the IEEE Smart Cities Community, which "brings together IEEE's broad array of technical societies and organizations to advance the state of the art for smart city technologies for the benefit of society and to set the global standard in this regard by serving as a neutral broker of information amongst industry, academic, and government stakeholders" [61].

In 2017, the IEEE P2784 (Smart City Planning Guide) [62] was proposed to develop a framework that mentions the processes and technologies for planning the smart city transformation. A smart city requires a unified process planning framework to use IoT to guarantee agile, interoperable, and scalable solutions that can be used and supported sustainably. The framework is a method for technology and cities integrators to plan for technology and innovative solutions for smart cities. Some of the most recent and first-of-a-kind standard initiatives from IEEE are presented in Tables 1.1–1.5.

In summary, this section has presented the need for international standards in smart city research and development. Some of the emerging standard projects are presented for various smart city domains. The next section examines the different smart cities projects worldwide and focuses on the standards examined and adopted.

Table 1.1 Recent Institute of Electrical and Electronics Engineers (IEEE) Standards in development for a smart grid and smart energy.

Year	Title	Scope
2016	1889–2018 (Evaluating and Testing the Electrical Performance of Energy Saving Devices) [63]	• Tests and evaluates energy saving devices' electrical performance • Measurement methods for observing the power generated or used by the observed load or generator: (i) without the energy saving devices connected to the circuit, (ii) with the energy saving devices connected and powered in the circuit

(*Continued*)

Table 1.1 (Continued)

Year	Title	Scope
		• Detailed protocols for testing circuits, the accuracy and details of evaluation instrumentation, and the sequence of the test measurements • Bespoke details for possible sources of measurement errors including from (i) wrong instrumentation connection, (ii) inadequate instrumentation, or (iii) wrong results interpretation • Can be used for all kinds of electrically connected energy saving devices that control electrical power given by a source and powering an electrical load
2016	P1922.1 (A Method for Calculating Anticipated Emissions caused by Virtual Machine Migration and Placement) [64]	• Methods to compute anticipated emissions created by virtual machine migration and allocation in distributed locations created by various electricity sources • Identify the anticipated electric grid's marginal emissions due to the change in power generation capacity, reflected by the additional power demand from server accepting the virtual machine and the network supporting virtual machine migration • Creates a technique to study anticipated gaseous (also greenhouse gases) and particle emissions created by virtual machine migration and allocation in distributed servers situated in various regions
2019	P2814 (Techno-economic Metrics Standard for Hybrid Energy and Storage Systems) [65]	• Techno-economic metrics for operation, construction, and development of electrical energy storage systems and renewable energy systems
2020	P2852 (Intelligent Assessment of Safety Risk for Overhead Transmission Lines Under Multiple Operating Conditions) [66]	• Artificial intelligence methods for a 3-D model of overhead transmission line and locational surroundings, to achieve a precise perception of overhead conductors to the ground and near buildings and trees • Identifies safety risk information including distance for overhead transmission lines in various operating conditions and provides an intelligent security assessment technique • Useful for intelligent evaluation and control overhead transmission lines safety risk during a typhoon, hot weather, icing, and alternative operating conditions

Source: From Lai et al. [A]/MDPI/CC BY 4.0.

Table 1.2 Recent IEEE Standards in development for smart health.

Year	Title	Scope
2014	1708–2014 (Wearable Cuffless Blood Pressure Measuring Devices) [67]	• Creates objective performance and normative definition for assessment of wearable cuffless blood pressure measuring devices • Works for all forms of the device or the vehicle where the device is attached or where it is embedded • Works for all kinds of wearable blood pressure measurement devices, such as epidermal and unconstrained blood pressure devices that have various operation modes • Limited to the assessment of devices that do not use a cuff while measuring • No assessment of all sphygmomanometers operated with an inflatable or occluding cuff for the nonintrusive assessment of blood pressure on the upper wrist or arm • Manufacturers guidelines to certify and confirm their products, possible purchasers or users to examine and choose potential products, and health care professionals to perceive the manufacturing practices on wearable blood pressure devices
2017	P3333.2.5 (Bio-CAD File Format for Medical Three-Dimensional (3D) Printing) [68]	• Establishes the Bio-Computer Aided Design format for 3-D printing from sectional scan image data comprising of volumetric and surface information • Related to medical 3-D printing services including pathologic services, anatomic models, and medical instrument printing with 2-D images, 3-D medical data, and alternative medical data
2017	P1752 (Mobile Health Data) [69]	• States requirements for mobile health data applications programming interface and standardized representations for mobile metadata and health data • Mobile health data consists of personal health data collated from mobile applications and sensors
2019	1847–2019 (Common Framework of Location Services for Healthcare) [70]	• The framework consists of location services for healthcare conceptual information model and location services for healthcare common terminology
2020	P2621.1 (Wireless Diabetes Device Security Assurance: Product Security Evaluation Program) [71]	• A connected electronic product security evaluation program framework consists of: 1) A method to use the ISO/IEC 15408 security evaluation framework in a security evaluation program 2) Allowing independent testing labs for security evaluation program

(*Continued*)

Table 1.2 (Continued)

Year	Title	Scope
		3) Confirming results from authorized labs 4) Defining and certifying novel security requirements and adjustments to security requirements, from protection profiles and security targets for security evaluation program 5) Assurance post-certification maintenance

Source: From Lai et al. [A]/MDPI/CC BY 4.0.

Table 1.3 Recent IEEE Standards in development for smart mobility and transportations.

Year	Title	Scope
2013	P1884 (Stray Current/Corrosion Mitigation for DC Rail Transit Systems) [72]	• Principles, methods, and data for engineering design, commissioning, installation, observing and evaluating; including mitigation and control techniques for stray currents in direct current rail transit systems
2013	P1883 (Electrical and Electro-Mechanical Bench Test Equipment (BTE) for Transit Rail Projects) [73]	• Design factors, documentation, construction materials, and the satisfactory requirement for bench test equipment for novel and current electrical and electromechanical equipment use in transit rail systems
2014	P2406 (Design and Construction of Non-Load Break Disconnect Switches for Direct Current Applications on Transit Systems) [74]	• Design, usage, and application of direct current nonload or no-load break disconnect switches for isolating direct current power distribution circuits in transit applications
2016	P2020 (Automotive System Image Quality) [75]	• Deals with key elements of image and quality for applications in automotive advanced driver assistance systems applications, includes recognizing current metrics and alternative meaningful information associated with these elements • Formulates objective and subjective evaluation methods for measuring automotive camera image quality • Presents tools and evaluation techniques to provide standards-based communication and contrast amid original equipment manufacturer and Tier 1 system integrators, and component vendors concerning automotive advanced driver assistance systems image quality
2017	P2685 (Energy Storage for Stationary Engine-Starting Systems) [76]	• Selection, installation design, sizing, installation, maintenance, and evaluating techniques for optimizing the performance and life of energy storage devices and associated systems for starting stationary engines

Table 1.3 (Continued)

Year	Title	Scope
		• Identify when energy storage devices need replacing. Energy storage devices and related systems including (i) nickel-cadmium and lead-acid batteries, (ii) supercapacitors and electric double-layer capacitors, (iii) air-start systems, (iv) start/control battery chargers, (v) parallel battery blocking diode systems, and (vi) monitoring systems

Source: From Lai et al. [A]/MDPI/CC BY 4.0.

Table 1.4 Recent IEEE Standards in development for smart education.

Year	Title	Scope
2018	P7919.1 (eReaders to Support Learning Applications) [77]	• Arranges and explains the eReaders abilities for working as a platform for education, training, learning, and using other approaches for developing these abilities • Methodology comprises of industry standards applications and may cover open-source reference code
2019	P2834 (Secure and Trusted Learning Systems) [78]	• Details technical specifications for privacy protection and student data management in learning online services and systems
2019	1876 (Networked Smart Learning Objects for Online Laboratories) [79]	• Techniques for saving, retrieving, and using online laboratories as interactive and smart learning objects • Defines techniques for combining online laboratories as smart learning objects in learning object repositories and learning environments
2020	1589–2020 (Augmented Reality Learning Experience Model) [80]	• Develop an overarching integrated theoretical model to identify interactivities across the real world, digital information, and the user and the conditions for augmented reality-assisted learning of the environment • Defines two data models and interface to Extensible Markup Language and JavaScript Object Notation for depicting learning activities and the learning environment as the tasks are executed

Source: From Lai et al. [A]/MDPI/CC BY 4.0.

1.7.2 Smart City Pilot Projects

Having examined the importance of international standards and the emerging ones, the following section presents some of the smart cities pilot projects from various countries. The focus is on the application of international standards. Following the alphabetical order of the continents, the smart cities pilot projects in Africa and Asia are presented in Tables 1.6 and 1.7, respectively.

In Australia, the Australian Government established the Smart Cities Plan in 2016 [97]. The Plan highlights the Government's vision for productive and habitable cities that boost innovation,

Table 1.5 Recent IEEE Standards in development for smart governance.

Year	Title	Scope
2017	P7005 (Transparent Employer Data Governance) [81]	• Methods to assist employers to validate to access, collect, share, utilize, store, and destroy employee data • Specific metrics and conformance needs on (i) when handling data from trusted global partners and (ii) how vendors and employers can react to handling data
2017	P7004 (Child and Student Data Governance) [82]	• Methodologies for stakeholders in certifiable and responsible student and child data governance
2020	P2145 (Framework and Definitions for Blockchain Governance) [83]	• A generic framework and nomenclature for explaining blockchain governance for all kinds of contexts and use cases, comprising of private, public, permissionless, hybrid, and with permission • The standard is normative concerning terminology and non-normative considering the particular blockchain systems and protocols design
2020	P2863 (Organizational Governance of Artificial Intelligence) [84]	• States the governance basis including safety, responsibility, accountability, transparency, and reducing bias, and procedures for performance auditing, useful implementation, training, and compliance in the formulation or deployment of artificial intelligence in organizations

Source: From Lai et al. [A]/MDPI/CC BY 4.0.

Table 1.6 Smart cities pilot projects in Africa.

Name	Description
Kenya	Konza will be a smart city with a connected urban ICT network that provides urban services connections and efficient management of those services on a great scale [85]. The city will connect the following four key services: infrastructure services including transportation, utilities, public safety and environment; citizen services including access and participation; city services including city information, planning, and development; business services including support services for local commerce. There is no information regarding the standards adopted in the Konza project
South Africa	Slavova and Okwechime [86] examined the broader transformative processes taking place in Africa and developed a vision of the future African cities. The authors showed the alignment of critical aspects of the smart city concept with the African Union's Agenda 2063. Several factors could impact on the transformative process including: (i) balancing the power dimension of smart city projects in Africa, (ii) the dichotomy dividing rural regions from urban spaces needs to be reduced, and (iii) the rapid adoption of technologies to implement a smart city. The relevant standards were not discussed by the authors. The Stellenbosch Smart Mobility Lab helps with developing Stellenbosch to be the first transportation leaning "Smart City" in South Africa [87]. The lab assists with the planning and implementation of mobility applications of the Smart City model. The applications include parking for enhanced vehicle distribution, real-time traffic and transport operations control systems, bicycle-sharing schemes, information services for commuters, and traffic planning platforms. Transport engineers employ big data gained from probe vehicles and human movement patterns as input into several of the aforementioned applications. There is no information regarding the standards adopted in the Smart City model

Source: From Lai et al. [A]/MDPI/CC BY 4.0.

Table 1.7 Smart cities pilot projects in Asia.

Name	Description
China	Alibaba's cloud project, City Brain, uses data collected from video feeds at traffic lights to relieve traffic congestion and gridlock in Hangzhou, China. The traffic management is 92% precise in recognizing traffic violations, aids emergency vehicles to reach their destinations 50% faster than before, and has permitted traffic speeds to grow by 15% [88]. City government leaders and planners can also utilize City Brain to overcome other pressing issues such alleviating a reduced water supply. Alibaba cloud had adopted numerous international standards to meet security compliance, including ISO 27001 and ISO 20000 [89]
Dubai	The Smart Dubai initiative improves the living standards of Dubai citizens [90]. There are more than 130 initiatives with the joint effort from government and private sector entities. Examples of initiatives include the Dubai Data Initiative, the Dubai Blockchain Strategy, the Happiness Agenda, the Dubai AI Roadmap, and the Dubai Paperless Strategy. Khan et al. [91] identified the best practices linked to Dubai's smart city and smart tourism. The city had a large amount of data that were unorganized, unstructured, and had very poor relationships. The Dubai Data initiative reinforces the Smart Dubai strategy and its applicable major components that enable the efficient exchange of data and information and modernizes the continuous connectivity for the private and public sectors. The innovative data-sharing initiative will be managed by international standards and best practices for safe, seamless, and fair exchanges of data [92]. However, there is no detail regarding the standards that will be adopted
Hong Kong	Hong Kong's smart city domains include smart mobility, smart living, smart environment, smart people, smart government, and smart economy [8]. The Next Generation GovCloud and Big Data Analytics Platform will modernize the current government cloud infrastructures and implement a new application architecture. Bureaux and departments can accelerate the development and delivery of digital government services, comprising big data analytics and artificial intelligence applications [93]. There is no information regarding the standards adopted in the Next Generation GovCloud and Big Data Analytics Platform. Ma and Lam [94] explored the interrelationships between several obstacles to open data adoption and suggested practical recommendations to improve open data development for smart cities. The study concluded that the lack of open data policy should be confronted as a matter of urgency in Hong Kong. An open mindset and IT literacy in the government organizations continue to be developed
Japan	Japan Smart Community Alliance is the leading authority to promote smart communities in Japan [11]. As in Feb. 2019, there are 259 members within the Japan Smart Community Alliance consisting of businesses from the manufacturing, electricity, gas, heat supply and water, information, and communications sectors. The alliance has also developed four working groups as follows [11]: • The International Strategy Working Group: Determines policy technological, and market developments concerning smart communities and shares information with alliance members and international organizations. The group creates strategies to assist the contributions of Japanese businesses in smart community development across the globe • The International Standardization Working Group: Expedites efforts in different fields in cooperation with Japan's Ministry of Economy, Trade, and Industry to attain international smart grid standardization. The group examines worldwide developments in smart grid standardization and encourages compliance in international standardization development. • Roadmap Working Group: Formulates smart community technology development roadmaps. The group supports technology development by creating scenarios for next-generation societies in which smart grid technologies have been implemented. The findings would create a synergistic effect between technology development and usage.

(*Continued*)

Table 1.7 (Continued)

Name	Description
	• Smart House and Building Working Group: Conducts activities to promote the dissemination of smart houses and smart buildings by creating work schedules for individual task, comprising the identification and maintenance of underlying critical devices, evaluating the development of individual task, and stimulating appropriate activities. Regarding smart cities projects, Woven City is a completely connected ecosystem run by hydrogen fuel cells to be constructed from early 2021 at the bottom of Mount Fuji [95, 96]. This "living laboratory," a 175-acre urban development in Higashi-Fuji will comprise full-time residents and researchers who will research and develop technologies including robotics, autonomy, smart homes, and personal mobility in a real-world setting. Buildings will be mainly built using carbon-neutral wood and adopt a mixture of robotic production methods and traditional Japanese joinery methods. Rooftops will be roofed in photovoltaic panels to generate solar power. Electricity will also be produced by hydrogen fuel cells. All homes will have state-of-the-art human assistance technologies, from maintaining basic needs and improving daily life to sensor-based artificial intelligence for monitoring personal's health. Woven City is an opportunity to utilize connected technology with security and integrity. The original plan is for 2000 people living in Woven City. The dwellers include Toyota employees and their families, industrial partners, retailers, retired couples, and visiting scientists. More residents will be invited as the project progresses. There is no information regarding the standards adopted in the Woven City.

Source: From Lai et al. [A]/MDPI/CC BY 4.0.

upkeep growth, and generate jobs. The Plan embodies a framework for a cities policy at the federal level. City Deals are the important drivers for executing the Smart Cities Plan. They are partnerships between the three levels of government and the community to strive for a shared vision for livable and productive cities. Standards Australia is the country's leading independent, nongovernmental, not-for-profit standards organization [98]. The organization is actively participating in national and international discussions on smart cities, including being involved in the ISO Technical Management Board United Nation Sustainable Development Goals Taskforce. The task force will: revisit the mapping of ISO standards to the Sustainable Development Goals; identify the importance of Sustainable Development Goals for ISO, leading to the design of a database that can be used by businesses and organizations to determine the useful standards in promoting Sustainable Development Goals; create guidance for committees on how to proactively identify the right partnerships including the United Nations and other international organizations; offer recommendations for which organizations including ISO should work in standards promotion to support Sustainable Development Goals.

The smart cities pilot projects in Europe, North America, and South America are presented in Tables 1.8 and 1.9, respectively.

In summary, the review on some smart cities developments from various countries and international standards shows:

1) There is a lack of discussions on the use of international standards in implementing smart cities. It is important to acknowledge the currently available standards in development when structuring and developing a smart city.

Table 1.8 Smart cities pilot projects in Europe.

Name	Description
Barcelona	Bakici et al. [99] examined the city of Barcelona and analyzed its Smart City initiative, including its urban policy implications. This article analyzes Barcelona's transformation in the areas of Smart City management, drivers, bottlenecks, conditions, and assets. The authors described the Barcelona Smart City model and examined the key factors of the Smart City strategy while considering living labs, Open Data, e-Services, smart districts, initiatives, and infrastructures. The Barcelona Smart City model consists of four domains including smart governance, smart economy, smart living, and smart people. The 22@ Barcelona region is a central point for innovation and economic development, as small-medium enterprises use the region as a test-bed to trial novel technologies. There is no information regarding the standards adopted in the 22@ Barcelona region
Romania	Pop and Proștean [100] studied the implementation approaches for different smart cities in Romania. The considered cities include Craiova, Napoca, Sibiu, and Timisoara. All Romanian smart cities offer mobile applications to citizens to notify them in real time of the timing for each individual public transport station. In Cluj-Napoca, Craiova, and Timisoara, traffic management lefts are used to monitor traffic lights. In addition, parking systems are available to offer citizens to pay for parking with short message service and identify the number of accessible parking places in real-time. International standards were not discussed on how the services were managed and achieved The Romanian Association for Smart City [101] is the leading authority of the Smart City Industry in Romania, which consists of professionals and experts from various industries. The association is also supported by over 200 national and international partners. The association aims to create creative-intelligent communities in Romania and achieve this by developing activities related to the Smart City ecosystem. The association has introduced 8 ISO international standards in legislation; however, there are no details regarding them Alba Iulia is located in the west-central part of Romania. The pilot project Alba Iulia Smart City has many distinctive features. The project promotes collaborative partnerships across governmental organizations, research institutions, local administration, companies, universities, citizens, and associations. The partnerships are not driven by commercial interests. The solutions are developed and examined by partner companies, with the local administration providing the required support and infrastructure. It is worth mentioning that there is no technical standard discussed for the Alba Iulia Smart City project [102]
Sweden	Stockholm aims to achieve environmental goals and efficient cooperation between various stakeholders, including the private and public sectors [103]. Kista Science City is an important venue for ICT research and development. The prominent ICT businesses including IBM and Ericsson settled in Kista during the 1970s and more than 1000 other ICT companies have joined. The city hosts one of the world's leading ICT clusters and largest urban business districts. Robèrt [104] examined a local travel planning network in Kista Science City where the travel demand is probable to surpass the capacity of the transport system in the future. There is no information regarding the standards adopted in Kista Science City
United Kingdom	Caird and Hallett [105] described that the British Standards Institution (BSI) collaborating with ISO has established a substantial body of work on smart city standards and urban performance metrics. BSI is the leading organization in developing smart city standards and urban performance metrics in the United Kingdom. Publicly Available Specification (PAS) 180 details industry-concurred understanding of smart city definitions and terms in the United Kingdom, to help develop a robust foundation for imminent standardization and good practices [106]. PAS 180 also helps enhancing smart cities understanding by setting a common language for designers, developers, clients, and manufacturers. The

(*Continued*)

Table 1.8 (Continued)

Name	Description
	standard will support industry to work more effectively and efficiently and reduce the probabilities of confusion in the supply chain. PAS 180 defines terms for smart cities encompassing smart city concepts for various infrastructure and systems' components. It covers processes, materials, applications, and methodologies PAS 181 is a smart city framework for city leaders to create, concur, and provide smart city strategies that can assist transform their city's capability to encounter its impending challenges and deliver its potential aspirations [107]. The smart city framework is based on current good practices and is a set of dependable and repeatable tasks that city leaders can use to support create and execute their smart city plans. The framework does not expect to describe a one-size-fits-all model for the UK cities. PAS 181 emphases on the enabling processes for the pioneering usage of data and technology, composed with organizational modification, can assist deliver the varied visions for potential UK cities in increased efficient, sustainable, and effective habits Manchester CityVerve [108] uses IoT technologies to transform the city. The program focuses on four aspects of transformation including "culture and public realm," "energy and environment," "health and social care," and "travel and transport." Milton Keynes is a fast-growing city in the United Kingdom. MK:Smart [109] is a large collaborative initiative to develop innovative solutions to support economic growth in Milton Keynes. The state-of-the-art "MK Data Hub" plays a critical role in the project which facilitates the acquisition and management of big data of city systems from numerous data sources. The data concerns with energy and water consumption, transport data, data from satellite technology, economic and social datasets, and crowdsourced data from social media or specialized apps. Caird and Hallett [105] examined both projects and concluded that the city authorities were unfamiliar with the smart city indicator frameworks [105]

Source: From Lai et al. [A]/MDPI/CC BY 4.0.

Table 1.9 Smart cities pilot projects in North America and South America.

Name	Description
Brazil	Macke et al. [110] described that the city of Curitiba, Southern Brazil to be a green, inclusive, and livable city. It is the top ten smartest cities globally speaking. Curitiba has several well-known sustainability programs. Effective leadership and devotion to intelligent transportation planning aided Curitiba to turn into a sustainable city and the standard for effective urban planning. The city's achievements are considered in six factors namely integrated urban planning, pedestrian priority zones, environmental awareness, waste management system, effective public transport system, and social justice. Smart living can be attained by delivering the four factors namely, community integration socio-structural relations, material well-being, and environmental well-being. International standards are not discussed in the work. Afonso et al. [111] studied Brazilian capital indicators and developed a maturity model called Brazilian Smart City Maturity Model to allow transform public databases into useful indicators to assist city managers in planning. The authors mentioned that the ISO 37120 standard provides 100 different performance indicators for cities. The standard consists of 17 themes, 46 core indicators, and 54 indicators that can help define public policies based on different domains. The model is an ongoing work
Canada	The Smart Cities Challenge is a national competition open to all municipalities, local or regional governments, and indigenous communities [112]. The Challenge promotes communities to adopt a smart cities approach to enhance the living

Table 1.9 (Continued)

Name	Description
	standards of citizens through data, innovation, and connected technology. The Challenge aims to address four areas including (i) to realize outcomes for residents, (ii) empower communities to innovate, (iii) forge new partnerships and networks, and (iv) spread the benefit to all Canadians Edmonton is experiencing a resident-led digital transformation supported by the city's council. The city developed the Business Technology Strategy, the first-of-its-kind in Canada to guide data usages, different technologies, and business solutions to enhance citizen's life [113]. The Edmonton's Smart City Strategy is an innovation ecosystem of academia, government, residents, and industry that abides by ISO 37106:2018. This standard is guidance for leaders in smart cities and communities across the private, public, and voluntary sectors concerning how to create a collaborative, open, digitally enabled, and citizen-centric operating model for their city that drives a sustainable future. The standard focuses on creating cities that (i) makes present and future citizen needs as the driver behind investment decision-making, planning and delivery of entire city spaces and systems, (ii) combine physical and digital planning, (iii) determine, foresee and react to emerging challenges in an agile, sustainable, and systematic manner, and (iv) develop changes in the capacity for joined-up delivery and innovation within organizational boundaries for the city [114] Saskatoon aims "to be the city that breaks the cycle of Indigenous youth incarceration by creating a new cycle focused on building purpose, belonging, security and identity" [115]. The ConnectYXE initiative is based on three pillars (i) to empower indigenous youth and their families by giving real-time information and choices for how to use services across the city, (ii) to work with partners by developing a data repository for all relevant programs and services accessible, and (iii) to exploit innovative technology by connecting systems, distributing data, and using artificial intelligence. The collective data will give a city-wide image of what is accessible and the needs of those supports at all times. This enables service providers and decision-makers to frequently study and recognize gaps, changes, and better approaches to respond to the needs. Presently, technical standards were not discussed in the proposal for ConnectYXE
United States of America	New York aims to become an equitable and smart city to improve government services and citizens' living standards [116]. The transformation contains multiple programs including "New York City Connected Communities," where the government develops computer lefts in the places with highly concentrated poverty rates. Over 100 lefts have been developed, which have improved the level of digital literacy and enhanced the quality of life by developing employment opportunities. The digital lefts are in parks, computer resource lefts, New York City Housing Authority Centers, recreation lefts, libraries, and senior citizen lefts. Another initiative is "LinkNYC" developed in 2014. The purpose was to develop a free ultra-high speed WiFi network to connect the whole city with free high-speed internet service. The city has installed over 7500 communication junctions with free WiFi network, domestic phone calls, and cell phone charging facility. Kansas City, Missouri is one of the smartest cities due to its successful technology utilization [117]. Along the two-mile track of the Kansas City Streetcar, a 15 million USD public–private partnership has facilitated the placement of 328 Wi-Fi access points, 178 smart streetlights that can monitor traffic patterns and available parking spaces, 25 video kiosks, pavement sensors, and video cameras. They are all connected by the city's fiber-optic data network. It was determined that the three smart city projects including New York City Connected Communities, LinkNYC, and the Kansas City Streetcar have not discussed technical standards

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2) With standards and technologies swiftly evolving, many cities need to avoid getting locked into one vendor's integrated solutions, which makes it more difficult for the city to share data with citizens, developers, and other cities.
3) International standards should be developed to address some of the most pressing challenges in a smart city, including potential solutions to a pandemic such as COVID-19 [118]. In combating the COVID-19, ISO has made some standards freely available to the public, including ISO 13688:2013 (Protective clothing – General requirements) and ISO 19223:2019 (Lung ventilators and related equipment – Vocabulary and semantics) [119]. Simultaneously, IEC also decided to make some standards and most relevant normative references for critical care ventilators free of charge to industries who are creating products or converting their existing assembly lines to ventilator production [120]. In the current pandemic, many organizations and governments are sharing or publishing data. For example, government health agencies are publishing data concerning regional cases and deaths; symptom trackers are distributing data with researchers and making data public; technology companies are obtaining mobility data which can help us to understand the impact of the coronavirus on our lives. Standards need to support data interoperability, the ability of services and systems that create, exchange, and use data to have clear, shared expectations for the contents, context, and meaning of that data [121, 122].

1.8 Challenges and Opportunities

By 2050, it is expected that 66% of the global population will dwell in urban regions [123]. The challenge will be to supply these populations with essential resources including sufficient energy, clean water, and safe food while simultaneously warranting complete economic, social, and environmental sustainability.

Several cities today have aspirations of transforming into the smart cities of tomorrow. However, the challenges to be overcome to accomplish this include the planning of a complicated plan that comprises public and private participants, product vendors, and information technology infrastructure providers. A smart city needs the foundation of standards-based information technology infrastructure that fulfills and supports a wide range of requirements and can adapt to novel technologies, such as advanced sensors, measurement and analytics tools, and solutions driven by machine learning and artificial intelligence. Smart city development requires support from public organizations, citizens, state and local government, and private enterprises. The benefits of a smart city include the creation of major prospects for sustainability, disaster prevention, business, public safety, and quality of life enhancements. However, there are key challenges that need to be addressed for a smart city including:

Commodification: As discussed by Gandy and Nemorin [124], a major concern regarding the smart cities' development is the motivation to support this worldwide initiative, from the pursuit of new markets by transnational corporations. Corporate organizations are keen to mine personal data, such as biometric data [125]. Data brokers could create consumer profiles including biometric information, and identities can be located and tracked as citizens move in a smart city. These profiles can also intensify commodification by mining the freshly available sources of data, with the ubiquity of sensors as dynamic data collection points.

Social and digital exclusion: In designing smart cities solutions, it is important to use suitable means to engage and empower population groups which are hard to reach, such as citizens living in poverty and/or social exclusion, migrants, younger and older people, or people with disabilities

[126]. Smart city technologies should be made affordable and able to be accessed by all groups of consumers. A smart city should be an age-friendly environment. The World Health Organization defines age-friendly environments as ones which "foster health and well-being and the participation of people as they age" [127]. These environments are accessible, equitable, inclusive, safe and secure, and supportive. Senior citizens may experience negative attitudes and discrimination based on their age. Creating age-friendly environments acknowledges diversity, fights ageism, and ensures that everyone has the opportunity to fully participate.

Privacy and surveillance: Privacy becomes a major concern when the data collected could lead to linking or identifying an individual, especially when gathered from numerous information sources. Data storage by governments is generally nontransparent. The likelihood for cross-sharing data within government services could lead to third parties to have access to the data, where the provider has no intention for it to happen. Zoonen [128] constructed a four-quadrant privacy framework to theorize if and how smart city technologies and urban big data produce privacy concerns among the people in these cities. The framework is developed according to two recurring dimensions in research toward people's concerns about privacy: one dimension signifies that people see specific data as more personal and sensitive than others, the other dimension signifies that people's privacy concerns vary according to the purpose for which data is gathered, in contrast to the surveillance and service purposes which are the most dominant. The work concludes that the smart technology options and the use of specific data and analytic tools are important factors to comprehend people's privacy concerns in smart cities, as well as to their awareness of what type of data to use to serve a purpose. A smart city should address (i) an applied need to substantiate the empirical relation between purpose and technologies, and (ii) to produce a theoretical and situated comprehension of people's privacy anxieties in smart cities.

In addition, building a smart city is a gigantic task as there are several working parts and components involved, namely the smart cities domains. Many smart cities are not constructed from scratch or all in a single attempt. Smart city development is a gradually evolving process that witnesses the city becoming smarter, bit by bit. As time progresses, the individual regions of smartness develop together and interconnect, but on the condition for them using the same consistent technical rules that are stipulated by technical standards.

Several researchers have reviewed smart city projects from different perspectives. Camero and Alba [129] explored the computer science and information technology used for a smart city. There is no agreement on a smart city definition and in fact, several definitions are being developed. One explanation is for the iterative process where cities become smarter as time progresses. There are very few studies on the inclusion of policy and urban planning recommendations in information technology and computer science literature.

Caird and Hallett [105] examined the creation of appropriate, valid, credible, and valuable approaches to smart city evaluation by studying conceptual, measurement, and evaluation challenges for five UK smart city projects. Caird and Hallett [105] identified that a critical challenge for evaluation design is in creating standardized smart city development and performance indicators that give useful citizen and city-centered evaluations. There is a significant amount of work on standardization and smart urban metrics driven by international standards organizations. Specifically, the Smart and Sustainable Cities and Communities Coordination Group advises on European interests and requirements concerning standardization on Smart and Sustainable cities and communities. The International Organization for Standardization (ISO) has concurred on standards for "Smart Community Infrastructures" performance metrics. ISO Technical Report 37150:2014 (Smart community infrastructures – Review of existing activities relevant to metrics) [130] reports community infrastructures including water, energy, waste transportation, and

Information and Communications Technology (ICT). The standard concentrates on the technical features of current activities which are available. Political, societal, or economic aspects are not studied in this standard. ISO Technical Report 37151:2015 (Smart community infrastructures – Principles and requirements for performance metrics) [130] details the principles and stipulates requirements for the definition, identification, optimization, and harmonization of community infrastructure performance metrics, and gives recommendations for analysis, including smartness, interoperability, synergy, resilience, safety, and security of community infrastructures. Funded by the European Union HORIZON 2020 program, the CITYkeys project [131] is an important European Commission EUROCITIES initiative that aims to create acceptable city performance measurement frameworks: key performance indicators. The initiative creates standardized data collection processes to increase the adoption rate of smart city solutions. It is anticipated that comparable, scalable, and replicable smart city solutions can be achieved across cities. The authors concluded that standardized smart urban metrics and indicators are not widely adopted by cities while the development of standards is at the early stages.

Hasija [88] examined the current global advancements in smart city initiatives. The study was categorized into three themes, namely data access and collection, end-user utility, and economic feasibility of different solutions. The economic viability is crucial to the success of a smart city initiative. The potential ideas to enhance city operations could not be delivered if they are economically unsustainable. For business strategies, prudent analysis is required to examine the trade-offs that determine the efficacy of such initiatives. A bike-sharing scheme is an affordable and convenient mode of transportation in China. However, not all bike-sharing companies are successful. Some of the issues contribute to the failure of bike-sharing initiatives include (i) no regulation: bikes could end up in different places and be dumped along city streets, (ii) lack of operational sustainability: many bike-sharing platforms do not need a security deposit, and (iii) no optimization: lack of consideration for how and where the bikes should be located to maximize utilization and to avoid bikes piling up on streets.

Anthopoulos [132] examined 20 smart cities projects of various scales in different countries and continents. Furthermore, the review documented the challenges that the cities meet as they work toward being a smart city. The review examines smart cities in relation to climate change, sustainability, natural disasters, and community resiliency. A smart city project is complex and expensive. Anthopoulous [132] first examined the project management guidelines and frameworks for agile and complex projects, including a smart city. ISO 21500:2012 Guidance on project management is an international standard that can be used by private or public organizations for all kinds of projects. The aim is to provide a guide to project managers on how to apply project management disciplines into a business environment to increase the possibilities for enhanced business results and project success. An important aspect is the use of the common language and processes by all project stakeholders, which enhances communication and cooperation. ISO 21500 gives a high-level description of concepts and processes to create good practices in project management. The cities reviewed focuses on the project management perspective including scope, organization, time, cost, quality, risk, and procurement. The smart city projects are well documented with great detail in the project development. However, there is a lack of discussion on technical standards of the smart city projects apart from project management.

Van Winden and Van den Buuse [133] analyzed the procedures of upscaling, concentrating on smart city pilot projects where numerous stakeholders with dissimilar missions, agendas, and incentives work together. If technical standards can be smoothly adapted to fit with the geospatial context, then the solution becomes more attractive to many cities. Numerous works on smart cities have been conducted and review literature for smart cities exists. However, most recent literature lacks discussions on an important topic of international standards for smart cities. International standards are technical standards developed by international organizations. International standards can greatly assist tailor-made solutions development for bespoke conditions of a city. Standards stipulate the anticipated level of performance and technologies compatibility. Standards are generic metrics that allow solutions to be benchmarked and compared.

1.9 Conclusions

Smart cities are intelligent and sustainable cities. It is well known that a smart city requires the use of novel technologies, including robust ICT infrastructures and sensor devices. First, this paper has revisited and identified some of the new smart city definitions. The definition of a smart city is continuing to evolve, and one must accept that different terminologies exist due to the different scope considered, e.g. the region and community involved. This paper then examines the smart city from the view of international standards. It is identified that numerous international standards are currently in development to develop a smart city and the old standards are being revised to become relevant to address current society needs. Six smart city domains were identified including smart energy, smart health, smart education, smart mobility, smart economy, and smart governance. There is a need for researchers and city developers to acknowledge the different kinds of standards currently available and in development, in order to build a city that is functional and sustainable. The review identified that international standards are by no means as yet pervasive: there is a need for smart city projects to present details on the international standards adoption, and its implications for a smart city. Well-defined standards allow meaningful comparisons among smart cities implementation. With the presence of many standard bodies, challenges exist if international standards are not agreed on by standards developers and users. This paper serves as a guide on international standards for smart city researchers and developers.

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References

1 Deakin, M. and Al Waer, H. (2011). From intelligent to smart cities. *Intell. Build. Int.* 3: 140–152.

2 Chamran, M.K., Yau, K.-L.A., Noor, R., and Wong, R. (2020). A distributed testbed for 5G scenarios: an experimental study. *Sensors* 20: 18.

3 Deakin, M. (2013). *Smart Cities: Governing, Modelling and Analysing the Transition*. Oxford, UK: Routledge.

4 ASEAN(2019). Smart Cities Framework. https://asean.org/storage/2019/02/ASCN-ASEAN-Smart-Cities-Framework.pdf (Accessed 1 May 2021).

5 Smart Cities Overview – Guide (2015). BSI Standards Publication. http://shop.bsigroup.com/upload/Shop/Download/PAS/30313208-PD8100-2015.pdf (accessed 22 April 2021).

6 Department for Business Innovation & Skills (2013). Smart Cities: Background Paper. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/246019/bis-13-1209-smart-cities-background-paper-digital.pdf (accessed 7 February 2021).

7 European Commission Smart Cities (n.d.). https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en (accessed 21 October 2020).

8 Office of the Government Chief Information Vision & Mission. https://www.smartcity.gov.hk/vision/ (accessed 7 August 2020).

9 IEEE Smart Cities. https://smartcities.ieee.org/images/files/pdf/IEEE_Smart_Cities-_Flyer_Nov_2017.pdf (accessed 7 May 2021).

10 Strategic Business Plan (SBP) SMB/6817/R (2019). International Electrotechnical Commission. https://www.iec.ch/public/miscfiles/sbp/SYCSMARTCITIES.pdf (accessed 1 May 2021).

11 Japan Smart Community Alliance (n.d.). Smart Community Development. https://www.smart-japan.org/english/ (accessed 22 April 2021).

12 Ministry of Housing and Urban Affairs (n.d.). Government of India Smart Cities Mission. http://smartcities.gov.in/content/innerpage/what-is-smart-city.php (accessed 7 August 2020).

13 Deloitte Consulting (n.d.). Deloitte Define Your Smart City Strategy. https://www2.deloitte.com/us/en/pages/consulting/solutions/smart-cities-strategies.html (accessed 7 May 2021).

14 Fedorova, E., Caló, A., and Pongrácz, E. (2019). Balancing socio-efficiency and resilience of energy provisioning on a regional level, case Oulun Energia in Finland. *Clean Technolies* 1: 273–293.

15 Lai, C.S., Jia, Y., Lai, L.L. et al. (2017). A comprehensive review on large-scale photovoltaic system with applications of electrical energy storage. *Renewable and Sustainable Energy Reviews* 78: 439–451.

16 Xu, X., Jia, Y., Xu, Y. et al. (2020). A multi-agent reinforcement learning based data-driven method for home energy management. *IEEE Transactions on Smart Grid* 11 (4): 3201–3211.

17 Wang, D., Wu, R., Li, X. et al. (2019). Two-stage optimal scheduling of air conditioning resources with high photovoltaic penetrations. *Journal of Cleaner Production* 241: https://doi.org/10.1016/j.jclepro.2019.118407.

18 Vaccaro, A., Pisica, I., Lai, L.L., and Zobaa, A.F. (2019). A review of enabling methodologies for information processing in smart grids. *International Journal of Electrical Power & Energy Systems* 107: 516–522.

19 Lasi, H., Fettke, P., Kemper, H.-G. et al. (2014). Industry 4.0. *Business and Information Systems Engineering* 6: 239–242.

20 Dong, Z., Lai, C.S., He, Y. et al. (2019). Hybrid dual-complementary metal–oxide–semiconductor/memristor synapse-based neural network with its applications in image super-resolution. *IET Circuits, Devices and Systems* 13: 1241–1248.

21 Dong, Z., Lai, C.S., Qi, D. et al. (2018). A general memristor-based pulse coupled neural network with variable linking coefficient for multi-focus image fusion. *Neurocomputing* 308: 172–183.

22 Taha, A., Wu, R., Emeakaroha, A., and Krabicka, J. (2018). Reduction of electricity Costs in Medway NHS by inducing pro-environmental behaviour using persuasive technology. *Future Cities Environ.* 4: 1–10.

23 Guerrero-Ibanez, J.A., Zeadally, S., and Contreras-Castillo, J. (2015). Integration challenges of intelligent transportation systems with connected vehicle, cloud computing, and internet of things technologies. *IEEE Wireless Communications* 22: 122–128.

24 Yin, J., Su, S., Xun, J. et al. (2019). Data-driven approaches for modeling train control models: comparison and case studies. *ISA Transactions* https://doi.org/10.1016/j.isatra.2019.08.024.

25 Hoel, T. and Mason, J. (2018). Standards for smart education–towards a development framework. *Smart Learning Environments* 5: 3.

26 Giffinger, R., Christian, F., Hans, K. et al. Smart Cities: Ranking of European Mid-Sized Cities. https://ec.europa.eu/digital-agenda/en/smart-cities (accessed 7 May 2021).

27 Hitachi (n.d.). Smart Water in Smart Cities. https://www.hitachi.eu/en-gb/social-innovation-stories/communities/smart-water-smart-cities (accessed 7 May 2021).

28 Hope, R., Foster, T., Money, A. et al. (2011). Smart Water Systems. Project report to UK DFID, April 2011. Oxford University, Oxford. https://assets.publishing.service.gov.uk/media/57a08ab9e5274a31e000073c/SmartWaterSystems_FinalReport-Main_Reduced__April2011.pdf (accessed 7 May 2021).

29 GOV.UK (2019). £1 Million Boost for UK Smart Waste Tracking. https://www.gov.uk/government/news/1-million-boost-for-uk-smart-waste-tracking (accessed 7 May 2021).

30 Interreg Europe (n.d.) Smart Waste Interreg Europe Innovation in Waste Management Policies. https://www.interregeurope.eu/smartwaste/ (accessed 7 May 2021).

31 Swan, M. (2015). *Blockchain: Blueprint for A New Economy*. Sebastopol, USA: O'Reilly Media, Inc.

32 Kumar, R., Strasser, T., Deconinck, G. et al. (April 2021). Guest editorial special issue on recent advances for intelligence in power and energy systems. *IEEE Transactions on Systems, Man and Cybernetics: Systems* 51 (4): 2036–2040.

33 Zhao, X., Lai, L.L., Wong, K.P. et al. (October 2017). Guest editorial special section on emerging informatics for risk hedging and decision making in smart grids. *IEEE Transactions on Industrial Informatics* 13 (5): 2507–2510.

34 Huang, C., Wang, L., and Lai, L.L. (2019). Data-driven short-term solar irradiation forecasting based on information of neighboring sites. *IEEE Transactions on Industrial Electronics* 66 (12): 9918–9927. https://doi.org/10.1109/TIE.2018.2856199.

35 Xu, F.Y., Cun, X., Yan, M. et al. (November 2018). Power market load forecasting on neural network with beneficial correlated regularization. *IEEE Transactions on Industrial Informatics* 14 (11): 5050–5059.

36 Zhang, J., Chen, X., Ng, W.W.Y. et al. (August 2019). New appliance detection for non-intrusive load monitoring. *IEEE Transactions on Industrial Informatics* 15 (8): 4819–4829.

37 Wu, X., Lai, C.S., Bai, C. et al. (2020). Optimal Kernel ELM and variational mode decomposition for probabilistic PV power prediction. *Energies* 13 (14): 3592.

38 Lai, C.S., Mo, Z., Wang, T. et al. (2020). Load forecasting based on deep neural network and historical data augmentation. *IET Generation Transmission and Distribution* https://doi.org/10.1049/iet-gtd.2020.0842.

39 Lai, C.S., Yang, Y., Pan, K. et al. (2020). Multi-view neural network ensemble for short and mid-term load forecasting. *IEEE Transactions on Power Systems* https://doi.org/10.1109/TPWRS.2020.3042389.

40 Wang, T., Lai, C.S., Ng, W.W.Y. et al. (2021). Deep autoencoder with localized stochastic sensitivity for short-term load forecasting. *International Journal of Electrical Power & Energy Systems* 130: 106954.

41 Lai, C.S., Zhong, C., Pan, K. et al. (September 2021). A deep learning based hybrid method for hourly solar radiation forecasting. *Expert Systems with Applications* 177 (1): 114941.

42 Yin, H., Dong, Z., Chen, Y. et al. (2017). An effective secondary decomposition approach for wind power forecasting using extreme learning machine trained by crisscross optimization. *Energy Conversion and Management* 150: 108–121.

43 Chen, X., Lai, C.S., Ng, W.W.Y. et al. (2021). A stochastic sensitivity-based multi-objective optimization method for short-term wind speed interval prediction. *International Journal of Machine Learning and Cybernetics* 12: 2579–2590.

44 Su, Q., Mi, C., Lai, L.L., and Austin, P. (May 2000). A fuzzy dissolved gas analysis method for the diagnosis of multiple incipient faults in a transformer. *IEEE Transactions on Power Systems* 15 (2): 593–598.

45 Liu, J., Fan, X., Zhang, C. et al. (July 2021). Moisture diagnosis of transformer oil-immersed insulation with intelligent technique and frequency-domain spectroscopy. *IEEE Transactions on Industrial Informatics* 17 (7): 4624–4634.

46 What is intelligent transportation system? Its working and advantages. https://theconstructor.org/transportation/intelligent-transportation-system/1120/ (accessed 7 May2021)

47 European Commission (n.d.). Case Study Summary: Smart Health. https://ec.europa.eu/growth/content/smart-health_en (accessed 7 May 2021).

48 Deloitte Development (2019). Smart Health Communities and the Future of Health. https://www2.deloitte.com/content/dam/Deloitte/lu/Documents/life-sciences-health-care/lu-smart-health-communities.pdf (accessed 7 May 2021).

49 Van Gheluwe, C., Lopez, A.J., Semanjski, I., and Gautama, S. (n.d.) Repurposing existing traffic data sources for COVID-19 crisis management. In *2020 IEEE International Smart Cities Conference*, Piscataway, NJ, USA (28 September – 1 October 2020).

50 Google (2020). COVID-19 Community Mobility Report. https://www.gstatic.com/covid19/mobility/2020-10-13_BE_Mobility_Report_en.pdf (accessed 7 May 2021).

51 Google (n.d.). See how your community is moving around differently due to COVID-19. https://www.google.com/covid19/mobility/ (accessed 7 May 2021).

52 Buckee, C.O., Balsari, S., Chan, J. et al. (10 April 2020). Aggregated mobility data could help fight COVID-19. *Science* 368 (6487): 145–146.

53 ISO (n.d.). What Are Smart Cities? https://www.iso.org/sites/worldsmartcity/ (accessed 7 May 2021).

54 ISO (n.d.). Standards. https://www.iso.org/standards.html (accessed 7 May 2021).

55 About the IEC. https://www.iec.ch/about/ (accessed 7 May 2021).

56 International Telecommunication Union (n.d.). About International Telecommunication Union (ITU). https://www.itu.int/en/about/Pages/default.aspx (accessed 7 May 2021).

57 World Council on City Data (n.d.). ISO 37120 World Council on City Data. https://www.dataforcities.org (accessed 7 May 2021).

58 IEC (n.d.). Editorial Team Standards Support Smart Cities. https://blog.iec.ch/2019/07/standards-support-smart-cities/ (accessed 7 May 2021).

59 Sang, Z. and Li, K. (2019). ITU-T standardisation activities on smart sustainable cities. *IET Smart Cities* 1: 3–9.

60 IEEE Standards Association. (n.d.). IEEE 802® – Keeping the World Connected. https://standards.ieee.org/featured/802/index.html (accessed 7 May 2021).

61 IEEE Smart Cities (n.d.). About IEEE Smart Cities. https://smartcities.ieee.org/about (accessed 7 May 2021).

62 IEEE Standards Association (n.d.). P2784 – Guide for the Technology and Process Framework for Planning a Smart City. https://standards.ieee.org/project/2784.html (accessed 7 May 2021).

63 IEEE Standards Association (2019). 1889–2018 – IEEE Guide for Evaluating and Testing the Electrical Performance of Energy Saving Devices. https://standards.ieee.org/content/ieee-standards/en/standard/1889-2018.html (accessed 7 May 2021).

64 IEEE Standards Association (n.d.). P1922.1 – Standard for a Method for Calculating Anticipated Emissions Caused by Virtual Machine Migration and Placement. https://standards.ieee.org/project/1922_1.html (accessed 7 May 2021).

65 IEEE Standards Association (n.d.). P2814 – Techno-economics Metrics Standard for Hybrid Energy and Storage Systems. https://standards.ieee.org/project/2814.html (accessed 7 May 2021).

66 IEEE Standards Association (n.d.). P2852 – Intelligent Assessment of Safety Risk for Overhead Transmission Lines Under Multiple Operating Conditions. https://standards.ieee.org/project/2852.html (accessed 7 May 2021).

67 IEEE Standards Association (2014). 1708–2014 – IEEE Standard for Wearable Cuffless Blood Pressure Measuring Devices. https://standards.ieee.org/standard/1708-2014.html (accessed 7 May 2021).

68 IEEE Standards Association (n.d.). P3333.2.5 – Standard for Bio-CAD File Format for Medical Three-Dimensional (3D) Printing. https://standards.ieee.org/project/3333_2_5.html (accessed 7 May 2021).

69 IEEE Standards Association (n.d.). P1752 – Standard for Mobile Health Data. https://sagroups.ieee.org/1752/ (accessed 7 May 2021).

70 IEEE Standards Association (2020). 1847–2019 – IEEE Recommended Practice for Common Framework of Location Services for Healthcare. https://standards.ieee.org/standard/1847-2019.html (accessed 7 May 2021).

71 IEEE Standards Association (2022). P2621.1 – Standard for Wireless Diabetes Device Security Assurance: Product Security Evaluation Program. https://standards.ieee.org/project/2621_1.html (accessed 7 May 2021).

72 IEEE Standards Association (n.d.). P1884 – Guide for Stray Current /Corrosion Mitigation for DC Rail Transit Systems. https://standards.ieee.org/project/1884.html (accessed 7 May 2021).

73 IEEE Standards Association (n.d.). P1883 – Recommended Practice for Electrical and Electro-Mechanical Bench Test Equipment (BTE) for Transit Rail Projects. https://standards.ieee.org/project/1883.html (accessed 7 May 2021).

74 IEEE Standards Association (n.d.). P2406 – IEEE Draft Standard for Design and Construction of Non-Load Break Disconnect Switches for Direct Current Applications on Transit Systems. https://standards.ieee.org/project/2406.html (accessed 7 May 2021).

75 IEEE Standards Association (n.d.). P2020 – Standard for Automotive System Image Quality. https://standards.ieee.org/project/2020.html (accessed 7 May 2021).

76 IEEE Standards Association (n.d.). P2685 – Recommended Practice for Energy Storage for Stationary Engine-Starting Systems. https://standards.ieee.org/project/2685.html (accessed 7 May 2021).

77 IEEE Standards Association (n.d.). P7919.1 – Requirements for eReaders to Support Learning Applications. https://standards.ieee.org/project/7919_1.html (accessed 7 May 2021).

78 IEEE Standards Association (n.d.). P2834 – Standard for Secure and Trusted Learning Systems. https://standards.ieee.org/project/2834.html (accessed 7 May 2021).

79 IEEE Standards Association (2019). 1876–2019 – IEEE Standard for Networked Smart Learning Objects for Online Laboratories. https://standards.ieee.org/standard/1876-2019.html (accessed 7 May 2021).

80 IEEE Standards Association (2020). 1589–2020 – IEEE Standard for Augmented Reality Learning Experience Model. https://standards.ieee.org/standard/1589-2020.html (accessed 7 May 2021).

81 IEEE Standards Association (2021). P7005 – Standard for Transparent Employer Data Governance. https://standards.ieee.org/project/7005.html (accessed 7 May 2021).

82 IEEE Standards Association (n.d.). P7004 – Standard for Child and Student Data Governance. https://standards.ieee.org/project/7004.html (accessed 7 May 2021).

83 IEEE Standards Association (n.d.). P2145 – Standard for Framework and Definitions for Blockchain Governance. https://standards.ieee.org/project/2145.html (accessed 7 May 2021).

84 IEEE Standards Association (n.d.). P2863 – Recommended Practice for Organizational Governance of Artificial Intelligence. https://standards.ieee.org/project/2863.html (accessed 7 May 2021).

85 Konza Technopolis Development Authority (n.d.). SmartCity. https://www.konza.go.ke/smart-city/ (accessed 7 May 2021).

86 Slavova, M. and Okwechime, E. (2016). African smart cities strategies for Agenda 2063. *Africa Journal of Managment* 2: 210–229.

87 Stellenbosch University (2013). Smart City. http://www.sun.ac.za/english/faculty/eng/ssml/research-focus/smart-city (accessed 7 May 2021).

88 Hasija, S., Shen, Z.-J.M., and Teo, C.-P. (2020). Smart city operations: modeling challenges and opportunities. *Manufacturing and Service Operations Management* 22: 203–213.

89 Alibaba Cloud (n.d.). Security & Compliance Center. https://www.alibabacloud.com/trust-center (accessed 7 May 2021).

90 Digital Dubai Authority (n.d.). Our vision is to make Dubai the happiest city on earth. https://www.smartdubai.ae (accessed 7 May 2021).

91 Khan, M.S., Woo, M., Nam, K., and Chathoth, P.K. (2017). Smart city and smart tourism: a case of Dubai. *Sustainability* 9: 2279.

92 Digital Dubai Authority (2019). Smart Dubai and Dubai Economy Launch New Data Initiative for Retail Sector. https://www.smartdubai.ae/newsroom/news/smart-dubai-and-dubai-economy-launch-new-data-initiative-for-retail-sector (accessed 7 May 2021).

93 Government Chief Information Officer (2022). Office of the Government Chief Information Officer The Government of the Hong Kong Special Administrative Region. https://www.ogcio.gov.hk/en/about_us/facts/doc/Fact_Sheet-OGCIO-EN.pdf (accessed 7 May 2021).

94 Ma, R. and Lam, P.T.I. (2019). Investigating the barriers faced by stakeholders in open data development: a study on Hong Kong as a "smart city". *Cities* 92: 36–46.

95 Toyota (2021). Woven City. https://www.woven-city.global (accessed 7 May 2021).

96 Clifford, J. (2020).Toyota to build a hydrogen-powered city of the future. https://blog.toyota.co.uk/toyota-woven-city-hydrogen-power (accessed 7 May 2021).

97 The Department of Infrastructure, Transport, Regional Development, Communications and the Arts (n.d.). Cities. https://www.infrastructure.gov.au/cities/ (accessed 7 May 2021).

98 Standards Australia (2020). Smart Cities Standards, August 2020. https://www.standards.org.au/getmedia/bfe42f98-011e-4798-8fa5-5b70c8a2a6bd/SA_Smart_Cities_Roadmap.pdf.aspx (accessed 18 August 2022).

99 Bakıcı, T., Almirall, E., and Wareham, J. (2013). A smart city initiative: the case of Barcelona. *Journal of the Knowledge Economy* 4: 135–148.

100 Pop, M.-D. and Proștean, O. (2018). A comparison between smart city approaches in road traffic management. *Procedia - Social and Behavioral Sciences* 238: 29–36.

101 Smart Cities in Romania. https://businessforsmartcities.com/load/118/presentation/2_alexa_dimitrscu_1_28a81.pdf (accessed 7 May 2021).

102 World Bank Group (n.d.). The City of Alba Iulia Alba Iulia Project Prioritization for 2014–2020. http://documents1.worldbank.org/curated/en/527401468190739988/pdf/Alba-Iulia-project-prioritization-for-2014-2020.pdf (accessed 7 May 2021).

103 City of Stockholm (2021). The Smart City. https://international.stockholm.se/city-development/the-smart-city/ (accessed 7 May 2021).

104 Robèrt, M. (2017). Engaging private actors in transport planning to achieve future emission targets – upscaling the Climate and Economic Research in Organisations (CERO) process to regional perspectives. *Journal of Cleaner Production* 140: 324–332.

105 Caird, S.P. and Hallett, S.H. (2019). Towards evaluation design for smart city development. *Journal of Urban Design* 24: 188–209.

106 BSI (n.d.). PAS 180 Smart Cities Vocabulary. https://www.bsigroup.com/en-GB/smart-cities/Smart-Cities-Standards-and-Publication/PAS-180-smart-cities-terminology/ (accessed 7 May 2021).

107 BSI (n.d.). PAS 181 Smart City Framework. https://www.bsigroup.com/en-GB/smart-cities/Smart-Cities-Standards-and-Publication/PAS-181-smart-cities-framework/ (accessed 7 May 2021).

108 O'Rourke, H. (2017). CityVerve and what makes Manchester a 'Smart City'. https://www.manchestereveningnews.co.uk/business/business-news/cityverve-smart-city-manchester-oxford--13048666 (accessed 7 May 2021).

109 Willetts, D. (n.d.). About MKSmart. http://www.mksmart.org/about/ (accessed 7 May 2021).

110 Macke, J., Casagrande, R.M., Sarate, J.A.R., and Silva, K.A. (2018). Smart city and quality of life: Citizens' perception in a Brazilian case study. *Journal of Cleaner Production* 182: 717–726.

111 Afonso, R.A., dos Santos Brito, K., do Nascimento, C.H. et al. (2015).Brazilian smart cities: using a maturity model to measure and compare inequality in cities. In *Proceedings of the 16th Annual International Conference on Digital Government Research*, Phoenix, AZ, USA (27–30 May 2015), pp. 230–238. New York, NY: Association for Computing Machinery

112 Infrastructure Canada (n.d.). Smart Cities Challenge. https://www.infrastructure.gc.ca/cities-villes/index-eng.html (accessed 7 May 2021).

113 City of Edmonton (2019). Smart City Challenge Edmonton Final Proposal. https://www.edmonton.ca/city_government/documents/CityofEdmontonSmartCitiesProposal_21MB.pdf (accessed 7 May 2021).

114 ISO 37106:2018(en) Sustainable cities and communities – Guidance on establishing smart city operating models for sustainable communities. https://www.iso.org/obp/ui/#iso:std:iso:37106:ed-1:v1:en (accessed 7 May 2021).

115 Connectyxe Smart Cities Challenge. https://www.saskatoon.ca/sites/default/files/documents/corporate-performance/communications/Engagement/connectyxe_saskatoon_march_5_2019.pdf (accessed 7 May 2021).

116 smartcity (2017). The Equitable City – A New Name for New York. https://www.smartcity.press/new-yorks-smart-city-initiatives/ (accessed 7 May 2021).

117 Smart Cities and the Journey to the "Cloud". https://www2.deloitte.com/content/dam/Deloitte/us/Documents/about-deloitte/us-about-deloitte-smart-cities-journey-cloud.pdf (accessed 7 May 2021).

118 Andersen, K.G., Rambaut, A., Lipkin, W.I. et al. (2020). The proximal origin of SARS-CoV-2. *Nature Medicine* 26: 450–452.

119 ISO (2021). COVID-19 response: Freely available ISO standards. https://www.iso.org/covid19 (accessed 7 May 2021).

120 IEC (n.d.). Access to key standards for critical care ventilators. https://webstore.iec.ch/webstore/webstore.nsf/xpFAQ.xsp?OpenXPage&id=GFOT-BNAEXA (accessed 7 May 2021).

121 Thereaux, O. Data and Covid-19: Why standards matter. https://theodi.org/article/data-and-covid-19-why-standards-matter/ (accessed 7 May 2021).

122 Mehta, S. (2021). What is data interoperability? https://datainteroperability.org (accessed 7 May 2021).

123 IEC (2020). Smart Cities. https://www.iec.ch/smartcities/introduction.htm (accessed 7 August 2020).

124 Gandy, O.H. Jr. and Nemorin, S. (2019). Toward a political economy of nudge: smart city variations. *Information, Communication & Society* 22: 2112–2126.

125 Sadowski, J. and Pasquale, F.A. (2015). The spectrum of control: A social theory of the smart city. *First Monday*, p. 20.

126 Smart Cities Marketplace (2016). Inclusive Smart Cities: A European Manifesto on Citizen Engagement. https://smart-cities-marketplace.ec.europa.eu/sites/default/files/Conference%20Inclusive%20Smart%20Cities%20-%20Brussels%2C%20November%2023rd%202016_0.pdf (accessed 7 August 2020).

127 Ageing and Life-Course. https://www.who.int/ageing/projects/age-friendly-environments/en (accessed 7 August 2020).

128 Van Zoonen, L. (2016). Privacy concerns in smart cities. *Government Information Quarterly* 33: 472–480.

129 Camero, A. and Alba, E. (2019). Smart City and information technology: a review. *Cities* 93: 84–94. https://doi.org/10.1016/j.cities.2019.04.014.

130 ISO/TC 268/SC 1 Smart Community Infrastructures (2015). Principles and Requirements for Performance Metrics. https://www.iso.org/standard/61057.html (accessed 30 March 2021).

131 Technical Research Centre of Finland (n.d.). Citykeys. http://citykeys-project.eu (accessed 7 August 2020).

132 Anthopoulos, L. (2019). *Smart City Emergence: Cases From Around the World*. Amsterdam, The Netherlands: Elsevier.

133 van Winden, W. and van den Buuse, D. (2017). Smart city pilot projects: exploring the dimensions and conditions of scaling up. *Journal of Urban Technology* 24: 51–72.