# Proposal for Information and Communications Technologies that Are Essential to Smart City Dimensions

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## 1 Introduction

For the first time in history, most of the world's population is now living in urban places. This is evident from the statistics of UN-Habitat; a survey from 2014 showed that the number of new cities developed globally was 694 [1]. Urban areas have also experienced increases in population in recent years. This shift is going to accelerate; a study from the United Nations showed that by 2030, numerous urban areas in Asia and Latin America are projected to have populations of more than 10 million people. Additionally, 70% of the total population of the world will be living in urban cities by 2050 [2, 3].

A variety of demands occur when there is urbanization. Keeping urbanization parallel to the development of cities has always been a struggle. Uncontrolled urbanization has led to the need for a model of a city called a "smart city" [3]. There are various different definitions of the term "smart city." The concept of a smart city was initiated from the term "information city" and incrementally evolved into an idea of an information and communications technology (ICT)–aligned smart city [4]. A city can be well defined as "smart" when its sociology, traditional (transport) infrastructure, and modern (ICT) infrastructure promote ecological economic growth that points to a high quality of life [5].

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The idea of a wired city is the fundamental development model, and connectivity is the reservoir for development [6]. In another definition of a smart city, it is a city that depends on a variety of smart computing technologies that are used for important infrastructure components and services [7]. When they are applied to the city's management, education, medical science, citizen safety, housing development, roading system, and living needs, they improve all operations and the data produced are used to analyze and make intelligent governing decisions, which will improve business overall [8]. Although many discussions have taken place in the European Community, the definition of the concept of the smart city is still not well distinguished [9]. With the rapid development of technology, there may be a need for smart cities to have a benchmark in terms of ICT services and infrastructures.

## 2 ICT and the Smart City

ICT is definitely an enabler for a smart city. It is inevitable that an integrated system will be needed to support public safety, security, and green technology with services such as leverage sensors that enable dynamic use of energy to improve the efficiency of carbon footprint reduction [10].

A well-planned city is always equipped with sustainability as its priority. The idea of technology in the smart city concept signifies the integration of systems, infrastructures, and services facilitated through enabling technologies [11]. To support efficient and high-quality life, cities must make extensive use of ICT and future information technologies through implementation of sophisticated monitoring, control tools, and applications, and robust infrastructures [12]. Application of big data supports the city's decision making, while the internet of things (IoT) can reduce wastage of energy and manage the safety of buildings and the city [13]. The ICT infrastructure that is needed to deploy smart infrastructure services and facilities includes fiber optics, Wi-Fi networks, wireless hot spots, and service-oriented information, as well as sensors, firmware, software, and middleware systems [14].

With ICT, the government can always have real-time data on their industrial, safety, and educational systems, and on their environment, to make critical reviews, amendments, and decisions. Thus, our communications ecosystem can be managed better with the support of ICT and can make automated decisions customized to the users' needs. Appropriate use of ICT is important for the development of cities. The planning of a city must use a SWOT (strengths, weaknesses, opportunities, and threats) analysis of the city, so that it covers the planning holistically, with a robust and long-term approach that looks 10 or even 20 years ahead [7]. This highlights the fact that with technology changing rapidly, there should be agile strategic planning for ICT infrastructures, applications, and services.

## 3 Smart City Dimensions

The importance of integrating the city's diverse systems—the roading system, vehicle management, educational institutions, health care, residential services, infrastructure, meals, public protection, and many more aspects that influence the quality of life of citizens—must be taken into consideration in developing a city with smart capabilities. The researchers in this field consider a smart city to be one that functions in a compact setting where devices are not operated in isolation [15]. An extensive evaluation of the literature shows that the meaning of a smart city is versatile. The description of a smart city draws together the characteristics of living and nonliving things with the advancement of information technology and information systems. Many factors and dimensions describing a smart city have been developed from analysis of the current literature. Many researchers, with the rationale of looking at the overall constitution of the smart city, have separated this concept of the smart city into many functions and dimensions [15]. ICT is common in every multidimensional aspect of a smart city and is a compulsory element in all dimensions of a smart city [16]. Smart city aspects include technology, infrastructure, governance, and economics [14].

The list of dimensions being considered has increased in recent studies performed by the Center of Local Technology at Vienna University, which have recognized six primary dimensions [17]. These dimensions are smart mobility, smart living, smart governance, smart people, a smart economy, and a smart environment. The researchers analyzed the dimensions on the basis of conventional and classical theories of city growth and improvement, competitiveness, transport, ICT, the economy, natural resources, high quality of existence, and individuals' participation in society. Lombardi has related the same six components to different elements of urban existence [18]. The smart financial system has been related to the presence of industries in the area of ICT or using ICT in manufacturing procedures.

Smart mobility refers to the use of ICT in contemporary transport technologies to enhance the experience of urban visitors. Those same six characteristics are deployed by means of other research to develop signs and smart city improvement strategies. This is further justified by the European Parliament's industry, research, and energy policies, which recognize and explore these six dimensions, and they are being utilized in practice by an increasing number of cities and policy makers. In its study titled "Mapping Smart Cities in the European Union," it has adopted these six dimensions to study smart cities in Europe.

The wealth of projects in the dynamic socioeconomic, technical, and policy environment probably offers an upward push to a wide variety of smart city dimensions. These can be associated with distinctive styles of citizen roles and connections, policy units, and implementation strategies. Each of those traits may additionally be mapped along with exclusive places, city sizes, funding preparations, and framework conditions and consequences. This research paper focuses on identifying technology on a smart city map along with identifying smart city dimensions in the literature study. This has allowed the researchers to determine applicable technological tasks that make a contribution to the formation of a smart city. Further to this, identification of possible technology correlations among dimensions will enable this research to derive underlying suggestions and best-practice recommendations for other smart city project initiatives.

## 4 Problem Statements

With urbanization being an inevitable process, it is hard to deal with the overwhelming issues related to pollution, infrastructure, congestion, and other social issues related to increasing population. There is an obvious abnormal growth pattern in the spatial distribution of people and resources. Although the smart city has been introduced to rectify many issues, Fatnassi points out that implementation of the smart city concept is limited by infrastructure that is technologically outdated, and some of it is incapable of handling the current needs of the citizens [10]. A smart city is a dynamically improving city. There are many challenges to its identity, depending on the infrastructure that is needed for the different dimensions it has. Such issues will affect its performance and have a disastrous impact on the economy unless money is pumped into the right infrastructures. The definition of ICT across articles related to the smart city is not explicit. The reason is that many technologies and deployment of these technologies are closely connected. The costs in these cities will be pushed to the limits, and there is also the possibility that the infrastructure may become obsolete too soon or redundancy will occur. ICT infrastructures and services have to be benchmarked well so that when a city is planned, the forecast of the expenditure can be accurate. First and foremost, things such as high bandwidth capacity and high-robustness classification help local governments to develop services that address their own unique requirements. Although it is important to know what data and databases are used, in reality "nobody has a comprehensive overall picture of the data and information systems of their city" [19]. Thus, the question arises as to which technology is a priority to be implemented first by policy makers.

## 5 Research Methods

This study adopted the approach of a systematic review, permitting a rigorous, independent, and literature-wide study of research outcomes, quality, and methods. A systematic review attempts to identify, appraise, and synthesize all of the empirical evidence that meets the prespecified eligibility criteria to fulfill the research findings. In this research, information on smart city case studies and technology usage were retrieved from the available scholarly research materials to propose essential technologies for smart city dimensions. The first step consisted of retrieving numerous smart city–related research papers. In this segment, the researchers performed a detailed search in the Springer Link, Science Direct, Institute of Electrical and Electronics Engineers (IEEE), Association for Computing Machinery (ACM), Google Scholar, ResearchGate, and other databases. In each of these databases, the phrases "smart city," "technology in smart city," and "smart city case study" were used to search for articles, proceedings papers, book chapters, and academic theses. Secondly, the researchers selected appropriate papers after studying each paper's title and abstract. A large collection of research papers from the wide literature exploration were examined for their importance in terms of smart city case studies, dimensions, and associated technology. Each research publication was analyzed by reading of the abstract, introduction, and overview. Articles that were not related to the research topic were eliminated from the sample. This process resulted in a sample of 60 articles.

The third phase consisted of detailed reading of the papers selected in the second phase, to select only those papers that were appropriate to the research objectives. The researchers conducted qualitative content analysis to retrieve sample smart city case studies with discussion of technology facilitated in a smart city. During this phase, there were challenges in retrieving papers related to the technology used in smart city case studies, since many papers had only limited or partial information on the technology used in urbanization development. However, the researchers performed content analysis on the technology used by identifying computing keywords in smart city case study discussions. The computing keywords "sensors," "infrastructure," "real-time," "storage of data," "data sharing," "integration," and other related keywords were taken into consideration in proposing the key technologies. As an outcome, this research compiled 33 papers published in international journals, in books, in proceedings, as web articles, or as research studies, as documented in the reference section of this research paper. The papers were analyzed qualitatively to identify how they conceptualized smart cities, smart city dimensions, smart city case studies, technology in the smart city, and other related information. The qualitative analysis identified 30 potential smart city case studies for this research. A detailed review of the technology keywords from the case studies enabled discussions on essential technology utilized in the smart city dimensions of smart mobility, smart living, smart governance, smart people, a smart economy, and a smart environment.

## 6 Case Studies

The following subsections describe case studies on the smart city dimensions. The technologies used for each case study were derived on the basis of keywords.

### 6.1 Smart Mobility Dimension

1. Seoul, South Korea (SEO)
   TOPIS—This transportation information center helps the public to obtain real-time data on city roads and subway traffic information [20]. The computing technology used includes big data, IoT, and the Global Positioning System (GPS).
2. Barcelona, Spain (BAR)
   Vehicle-to-infrastructure (V2I) and vehicle-to-vehicle systems transmit data between vehicles and the surrounding environment, and directly between nearby vehicles. These data offer solutions to many problems related to security, management, and entertainment on the road [21]. The computing technology used includes IEEE 802.11 N, infrared (IR), and dedicated short-range communication (DSRC).
3. Paris, France (PRS)
   Grand Nancy—This is an application to derive the best and alternative routes by using an ad hoc information system on the city by using bike sharing, biking, and tramways [20]. The computing technology used includes IoT, mobile applications and infrastructure, 4G, and 5G.
4. Singapore (SG)
   Smart logistics system—This has been implemented to provide real-time transport data to make route decisions as efficient as possible [20]. The computing technology used includes IoT, mobile applications and infrastructure, 4G, and 5G.
5. Thessaloniki, Greece (THES)
   Traffic control center—This system is used to control situations with real-time information and dynamically monitor traffic signals. A mobility planner provides citizens with real-time traffic data and provide citizens with the shortest, most affordable, and convenient routes [21]. The computing technology used includes big data, GPS, and artificial intelligence (AI).
6. Stockholm, Sweden (STOC)
   Intelligent transport system—This smart traffic system reduces traffic, reduces emissions, and increases use of public transportation with greater integration between systems and modes. The system provides real-time information sharing and responsiveness [22]. The computing technology used includes big data, GPS, and cloud computing.

### 6.2 Smart Living Dimension

1. Washington DC, USA (WHT)
   PA2040—This system manages light-emitting diode (LED) street lights. The LED lights are sensor based and designed to improve visitors' experience, and

are managed remotely [20]. The computing technology used includes big data, IoT, cloud computing, and Wi-Fi.

2. Los Angeles, USA (LA)
   LA Express parking program—This is used to dynamically allocate parking spaces. The system is calculated on the basis of hours of usage and frequency of usage [20]. The computing technology used includes GPS, big data, and Wi-Fi.
3. Nordhavn, Denmark (NOR)
   Smart city neighborhood—This is an ICT-endowed carbon-neutral and manageable neighborhood system. It includes solar cells, heating stations, waste to energy, water consumption, transportation, cultural events, management of urban water, and adaptation to climate changes [21]. The computing technology used includes big data, IoT, cloud computing, and mobile technology.
4. Kyoto, Japan (KYO)
   Eco-city—This nationwide project has been created to create a center of awakening culture, knowledge, and study. The eco-city is a homegrown initiative for many organizational labs and study centers to possess reliable technical capability with technological infrastructure [20]. The computing technology used includes mobile technology, Wi-Fi, nanotechnology, and big data.
5. New York, USA (NY)
   Real-time crime centers (RTCCs)—These have reduced the crime rate by 27% and useintegrated emergency response solutions for public safety through citywide surveillance, which is centrally monitored. Big data is used to decipher crime patterns, using analytics and visualization [10]. The computing technology used includes GPS, big data, Wi-Fi sensors, and mobile technology.
6. South Korea (KOR)
   Public safety—The launch of this system is intended to prevent foot and mouth disease, harnessing big data links to animal disease overseas, customs/immigration records, breeding farm surveys, livestock migration, and workers in the livestock industry [12]. The computing technology used includes big data and mobile technology.

### *6.3 Smart Governance Dimension*

1. Queensland, Australia (Que)
   Dial before you dig—This system is designed to guard the underground pipe network, cabling, and pits by locating the devices before any upgrades, in order to prevent major damage, which can be disastrous [20]. The computing technology used includes radiofrequency identification (RFID), GPS, and mobile technology.
2. Amsterdam, Netherlands (AMS)
   ICT-enabled citizen participation platform—This permits resident involvement in open data platform strategies, crowd sourcing, and integrated platforms. The Open Data Smart City caters for games/competitions to develop systems and to

yield electronic services, based on public data, in order to develop reliable public services and involve residents in service project creation [21]. The computing technology used includes cloud computing and big data.

3. Orlando, America (ORL)
   Emergency and response—OCAlert.Net is an alert system to enable contact with society, citizens, or communities during an emergency by instantly sending messages to email addresses, cell phones, and smartphones, enabling connection to real-time directions [23]. The computing technology used includes GPS, big data, Wi-Fi sensors, and mobile technology.
4. Prague, Czech Republic (PRA)
   University Hospital Motol—In this city, the major medical care providers have accomplished the initial installation of a Grid Medical Archive Solution. This is an expert system for integrating patient data and is focused on integrated solutions with a group of specialists who collaborate across the network [22]. The computing technology used includes AI, big data, and cloud computing.
5. Spain (SPA)
   Health System In Transition (HiT)—A regional integrated system has been implemented that allows patients to go to different health centers in the region, with the certainty that the doctors there will have access to their complete patient data, making treatment faster and more accurate [22]. The computing technology used includes AI, big data, and cloud computing.
6. Canada, Quebec City (QUE)
   Zap Quebec—This provides a Wi-Fi snow-clearing management system by providing sensors on each snow-clearing machine, intercity connections, information system integration, open data concepts, and online transportation control [15]. The computing technology used includes Wi-Fi, big data, IoT, and cloud computing.

## *6.4 Smart People Dimension*

1. Birmingham, UK (BIR)
   Birmingham is a city with a fast-growing population that aims to become an ecological city and empower trades, society where inhabitants flourish in a cooperative manner. This is being realized by the establishment of city authorities, platforms, and environments that blend and control aptitude across digital citizens [21]. The computing technology used includes GPS, big data, Wi-Fi sensors, and mobile technology.
2. New York, USA (NY)
   A system powered by IBM helps the city to avoid fires and protect first responders, and helps residents to process tax refund claims. MyNYCHA (from the NY Housing Authority) is a cellular system that allows citizens or home occupants to edit, implement, submit, list, preview, and update maintenance service records, view alerts and outages related to developments, view scheduled

check-ups, and save contact details by using smart mobile phones and tablets [20]. The computing technology used includes big data, IoT, and Wi-Fi.

3. Seoul, Korea (SEO)
   Enhancing public health and safety—The U-Seoul Safety Service employs location-based services and CCTV, letting guardians monitor kids' locations and notify the appropriate personnel in any emergency situation. Besides that, the U-Health Care System offers medical checks and arranged medical care for incapacitated people and senior citizens with restricted mobility. There is also the creation of a charging infrastructure to ease large-scale introduction of electric vehicles (EVs), etc., and the building of next-generation traffic systems connecting cycles and public transportation [4]. The computing technology used includes big data, cloud computing, mobile technology, and IoT.
4. Friedrichshafen, Germany (FRIE)
   Edunex—This is an online education system. It is a learning website platform for schools. The secured Edukey provides secure access to Edunex by using biometrics. The system is designed to help schoolkids with new educational concepts and innovative tools [15]. The computing technology used includes big data, biometrics, and cloud computing.

## *6.5 Smart Economy Dimension*

1. Amsterdam, the Netherlands (AMS)
   Budget monitoring—This is a way to enable people to screen, assess, and proactively join in decisions on residents' policy making and government expenditure. It gives citizens the power, information, and self-belief to take appropriate action to live in comfortable surroundings [21]. The computing technology used includes big data, cloud computing, and IoT.
2. Helsinki, Finland (HEL)
   RFIDLab Finland—This is a neutral nonprofit organization, aiming to improve the operational effectiveness of organizations with the latest technology. This service is presented to help organizations with the business potential of RFID and near-field communication (NFC) technologies to implement networks and enable development creativity. It caters for prime users of RFID technology—for example, in manufacturing, sales, retail, logistics, and service provision industries—and those businesses that need to expand their business processes or create new businesses ventures [24]. The computing technology used includes RFID and NFC.
3. Luxembourg City, (LUX)
   HotCity SA—This system has been created to commercialize online access to the HotCity network. This is to mutualize the HotCity network and city apps with cities and private organizations such as hotels, campsites, and banks. Next-generation traffic systems have also been constructed, linking bikes and public transport [25]. The computing technology used includes Wi-Fi, big data, and mobile technology.

4. Seattle, America (SEA)
A government portal supports 20+ languages, allowing open data and open government. This is an open data site of the federal government, and its objective is to make management more transparent and responsible. Opening government data increases resident contributions to government, generates opportunities for economic development, and notifies decision making in both the private and public sectors [15]. The computing technology used includes Wi-Fi, big data, and cloud computing.

### *6.6 Smart Environment Dimension*

1. Seoul, Korea (SEO)
Increasing energy efficiency—This allots smart homes with smart meters that control electricity. These controllers can display power usage and save energy. This technology enables street lamps/lights that automatically regulate their light output according to the outdoor luminance [20]. The computing technology used includes Wi-Fi, big data, and mobile technology.
2. Beijing, China (BEI)
The city of Beijing was chosen as a place for a pilot study on the EU–China Partnership on Urbanization 2013. The objective of this project is to advance intelligent amenities in medical care, expenditure, road traffic, and citizens' lives. This will importantly enhance citizens' daily lifestyles. An "Atos World" grid has been established for China to attract international skilled people to support China to develop energy networks, along with resolving problems related to urbanization. The solutions provided include automated meter reading and an automated grid [21]. The computing technology used includes RFID and NFC.
3. Barcelona, Spain (BAR)
An IoT program has been launched, with a powerful base. This project includes about 500 kilometers of fiber-optic cable within the city area. The establishment of this widespread network infrastructure commenced 30 years ago, whereby the city was linked with two community buildings with early introduction of fiber technology. The current fiber network delivers 90% fiber-to-the-home handling and provides a main support for unified city systems [26]. The computing technology used includes RFID and NFC
4. Australia (AUS)
Smart grid—This consists of sensors and smart meters to reduce energy consumption and help protect the environment in terms of use of renewable energy sources (RES) [27]. The computing technology used includes RFID, IoT, and NFC.
5. UK
Natural resources and energy—The aim of this project is to address climate change and its impacts on the availability of necessary water and food, local strains, and global solidity and safekeeping by carrying out in-depth scrutiny

on multiple information channels [12]. The computing technology used includes IoT, big data, and cloud computing.

## 7 Findings

The smart city could be defined as a complex ecosystem characterized by the intensive use of ICT. Smart city development is a response to address the issues of urbanization and the needs for flexibility and agility in delivering services to citizens. The smart city can be a solution to many known problems in urbanization. In this study, the researchers conducted a systematic review of various technologies applied in the smart city dimensions. With the sample of these 30 smart city projects, the researchers undertook analysis to identify the forms of technologies utilized in the smart city dimensions. The results of the analysis in this study were mapped to the six dimensions of the smart city mentioned earlier. Referring to Sect. 6, technologies used in the dimensions of smart city projects or applications were figured from the keywords in the case studies mentioned in Sect. 6. Hence, the findings resulted in many technologies being mapped to the dimensions of smart mobility, smart living, smart governance, smart people, a smart economy, and a smart environment. Table 1 illustrates the smart city technologies mapped to the smart city dimensions. In this research, around 30 samples of smart city projects were reviewed randomly in different regions. For each smart city project, the researchers analyzed the types of projects implemented and the associated technologies identified on the basis of the keywords.

As Table 1 shows, the technologies used in the smart mobility dimension are big data, IoT, cloud computing, GPS, Wi-Fi, DSRC, mobile technology, and AI; those used in the smart living dimension are big data, IoT, cloud computing, nanotechnology, GPS, Wi-Fi, and mobile technology; those used in the smart governance dimension are big data, RFID, IoT, cloud computing, GPS, Wi-Fi, mobile technology, and AI; those used in the smart people dimension are big data, RFID, IoT, cloud computing, Wi-Fi, mobile technology, and biometrics; those used in the smart economy dimension are NFC, big data, RFID, IoT, cloud computing, Wi-Fi, and mobile technology; and those used in the smart environment dimension are NFC, big data, RFID, IoT, cloud computing, Wi-Fi, mobile technology, and AI.

## 8 Discussion

For the purpose of this research, the five most widely used forms of technology in the smart city dimensions were derived through a systematic approach, as shown in Table 1. This is denoted by the 19 smart cities listed as using big data technologies in their applications. Besides that, 9 smart cities have incorporated IoT in their application development. Along with this, 11 smart city case studies revealed the

**Table 1** Common information and communications technologies (ICT) used across the dimensions

| Type of ICT | Dimensions | | | | | |
|---|---|---|---|---|---|---|
| | Smart mobility | Smart living | Smart governance | Smart people | Smart economy | Smart environment |
| NFC | | | | | HEL | AUS, BEI |
| Big data | BAR, PRS, SEO, STOC, THES | KYO, LA, NOR, NY, WHT | ORL, PRA, QUE | BIR, FRIE, NY, SEA, SEO | AMS, LUX | BAR, BEI, UK |
| RFID | | | AMS, QUE | BIR | HEL | AUS, BEI, SEO |
| IoT | SEO, SG | NOR, WHT | QUE | FRIE, NY, SEO | AMS | AUS, BAR, SEO, UK |
| Cloud computing | STOC | NOR, WHT | AMS, PRA, QUE | BIR, SEA, SEO | AMS | UK |
| Nanotechnology | | KYO | | | | |
| GPS | BAR, SEO, STOC | LA, NY | ORL, QUE | | | |
| Wi-Fi | THES | KYO, LA, NY, WHT | QUE | NY, SEA | LUX | BAR |
| DSRC | BAR | | | | | |
| Mobile technology | PRS, SG | KYO, NOR, NY | ORL, QUE | SEO | LUX | BAR |
| Artificial intelligence | THES | | PRA | | | SEO |
| Biometrics | | | | FRIE | | |

*AMS* Amsterdam, *AUS* Australia, *BAR* Barcelona, *BEI* Beijing, *BIR* Birmingham, *CPH* Copenhagen, *DSRC* dedicated short-range communication, *FRIE* Friedrichshafen, *GPS* Global Positioning System, *HEL* Helsinki, *IoT* internet of things, *JPN* Japan, *KYO* Kyoto, *LA* Los Angeles, *LON* London, *LUX* Luxembourg City, *NFC* near-field communication, *NOR* Nordhavn, *NY* New York, *ORL* Orlando, *QUE* Quebec City, *PRA* Prague, *PRS* Paris, *RFID* radiofrequency identification, *SEA* Seattle, *SEO* Seoul, *SG* Singapore, *SPA* Spain, *STOC* Stockholm, *THES* Thessaloniki, *WHT* Washington, DC usage of cloud computing in their applications. Mobile technology was used in ten of the smart city case studies. Although this technology is the one most widely used by the population around the world, the infrastructure supporting mobile technology may be inadequate to support newer systems and applications; for example, use of autonomous vehicles requires very well supported mobile technology. Most of the cities mentioned in Table 1 are equipped with 3G and 4G technology. Nine of the smart cities listed in Table 1 use Wi-Fi. The findings prove that the forms of ICT that are commonly used across the smart city dimensions are big data, IoT, cloud computing, mobile technology, and Wi-Fi. The widely used big data is an essential technology for the development of a smart city. Hence, big data in smart cities involves a large collection of sensors, databases, emails, websites, and social media, which provide sophisticated data analysis mechanisms to search and extract valuable patterns and knowledge from IoT and the smart city [14]. Thus, the volume of valid urban data is massive in the smart city; therefore, advanced big data analytical tools for data validation technologies with the capability for high-speed processing and consistency need to be engaged in order to confirm unaffected real-time authentication. The core technology needed for enactment of a smart city is IoT, supported by components such as electronics, sensors, networks, firmware, and software, which are essential for its deployment [14]. In addition, a wide collection of data can be extracted from different perspectives of the city via a distributed wireless sensor network constituting IoT, and these measured data can provide solutions for the relevant authorities and contribute to better city administration [14, 28, 29]. IoT is connected heavily by RFID, IR, and GPS sensors, which connect buildings, infrastructures, transport, networks, and utilities through ICT. Ultrasmart sensors and video authentication technology that use Wi-Fi, IoT, and mobile technology networks throughout the earth, sea, and air make it conceivable to deliver a diversified smart city service concerning all elements of urban life. In addition, cloud computing technology is inevitably a part of the infrastructure that caters to data storage remotely. Stakeholders can use cloud computing for information sharing and for immediate diagnosis of actions, accidents, and incidents [28]. Diagnosing the data and providing alerts and solutions can be done using big data analysis. On the other hand, broadband cellular connectivity has played an important role in the evolvement of IoT devices, which not only accommodate global reach, scalability, and diversity but also support a full range of IoT applications; it is expected that by 2025, 50% of mobile network data traffic will be information from IoT devices [30]. There is evidence that mobility is an inevitable challenge because of the rapid development in vehicular communication and cellular technology; thus, support for infrastructure such as fiber optics and mobile communication infrastructures such as 4G and 5G is important for the efficient functioning of a city [7].

## 9 Conclusion

The wide variety of smart city case studies with essential technologies in this research study will help smart city researchers and be useful for future studies. The research conceptualizes six dimensions in a smart city, the smart applications in each dimension, and the associated technology usage in the dimensions of smart mobility, smart living, smart governance, smart people, a smart economy, and a smart environment. The research underpins many smart applications with derived technology such as big data, cloud computing, IoT, Wi-Fi, mobile technology, GPS, and other technology. Therefore, this research contributes information on essential technologies that are widely used in the six dimensions covering the initiating technological factors in planning of information technology infrastructure in a smart city.

## 10 Future Work

For future research, there should be a thorough study on creating a benchmark or guideline for essential ICT infrastructures, and it should be revised appropriately within a set time frame. This study will continue to evolve in the future, as the authors will explore more smart city case study initiatives, taking into consideration various smart city enablers such as vendors, service providers, and new technologies. There should also be a study to define smart city terminology specific to continents and dimensions.

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