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The Fourth Industrial Revolution in the Digital Economy: How to Realize It With Smart Cities as a Practical Measure?[1]

S.C. Park

Sang Chul Park — Professor at Graduate School of Knowledge based Technology and Energy, Tech University of Korea, Tel: +82 31 8041 0324 (O), scpark@tukorea.ac.kr

Abstract

The concept of the smart city represents the highest level of the Fourth Industrial Revolution (FIR) along with smartphones, smart homes, and smart factories. Therefore, most governments around the world have tried to build smart cities in order to strengthen their urban competitiveness and improve the quality of life for their citizens in the digital economy. North America, the European Union (EU), and Asia have already carried out several pilot projects to build smart cities based on private-led, public-private partnerships, and public-led strategies, respectively. Smart cities can improve overall problems and resolve difficulties by 10–30% on average, which is regarded as an overall benefit of smart cities. At the same time, they can contribute to labour force disruptions, digital discrepancies, and threats to social coherence and inclusiveness, all of which result in socio-economic and political costs. The author examines the roles smart cities can play in the digital economy and in the completion of the FIR and focuses on whether smart cities can contribute to the creation of new opportunities for global economic growth as a new industry in the digital economy. Finally, the author examines the challenges of transforming digitalization and smartness in reality and highlights future perspectives for the FIR in practical terms.

Keywords: Smart city, Fourth Industrial Revolution, digital economy, economic growth, quality of life

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Introduction

Smart cities represent the highest level of the Fourth Industrial Revolution (FIR) which is based on hyper automation and hyper connectivity, starting with smartphones, smart homes, and smart factories. In reality, these have already been commercialized in product and services. The establishment of smart cities signals the completion of the FIR and its presence in our daily lives. The motivation to build smart cities is to facilitate the highest quality of life for their residents while optimizing the resources that smart cities require. By doing so, smart cities are able to strengthen social and economic development, which contributes to overall sustainable economic and urban development [Park, 2018; Schwab, 2016; Suvarna et al., 2020].

According to the United Nations (UN), the global urban population increased from 750 million in 1950 to 4.2 billion in 2018, a more than 550% increase in nearly seven decades. The urban population in 2018 accounted for 55% of the total global population. This growth is expected to continue, reaching up to 70% of the global total population by 2050. Rapid urban migration can cause severe problems in various areas such as traffic, housing, education, labour market, environment, and so on. To tackle these problems, a multitude of global projects across the U.S., the European Union (EU), Asia Pacific, and Middle East regions have emerged around the concept of smart cities in thenlast decade [Anthopoulos, 2015; UN, 2019].

There is no single or standardized definition of smart cities as the concept is still in flux and subject to debate. As such, definitions vary across Organisation for Economic Co-operation and Development (OECD) countries and institutions according to the geopolitical context and the specific issues. However, a common theme of various definitions of a smart city is that information and digital technologies can provide intelligent and innovative solutions for an urban ecosystem in areas such as infrastructure, transport, healthcare, governance, and security, which play core roles in the digital economy. Smart cities can make urban service delivery more efficient and can strengthen the overall competitiveness of a community, while digital innovation and technology remain central to the smart city concept. The key question is whether investment in digital innovation and technology can improve the well-being of citizens and contribute to sustainable urban development. This is central to the OECD's definition of smart cities as initiatives or approaches that effectively leverage digitalization to boost citizen well-being and deliver more efficient, sustainable, and inclusive urban services and environments as part of collaborative and multistakeholder processes. At the same time, however, critics of smart cities point to their profit-orientation and superficiality of solution, exclusive use and decision-making, imperfection of privacy protection, and control of urban living in general. Indeed, it is not easy to measure and explain the actual positive effect of urban digitalization in concrete terms [Haarstad, 2017; Hatch, 2012; Kitchen, 2016; OECD, 2019; Suvarna et al., 2020].

Despite the fact, the smart city has been a new phenomenon, which is very infected particularly since the global financial crisis (GFC) in 2008. The main reasons for the emergence of the Smart City Initiative (SCI) are to create a sustainable model for cities and maintain the high quality of life to their citizens. Given that the impetus for the development of smart cities is to create a sustainable urban model and a high quality of life for residents, it is important to note that smart cities are emerging as a significant industrial sector in the digital economy. The total value of the global smart city market is projected to exceed $1.2 trillion by 2021 and $2.5 trillion by 2025. With such rapid growth in the global market, the most dynamic aspect of smart cities must be the evolution of roles and relationships between the key actors involved in envisioning and creating them [Lom, Pribyl, Svitek, 2016; PWC, 2019]. Therefore, the concept of the smart city involves not only technical aspects, but also various socio-economic, legal, and environmental aspects.

In face of such rapidly changing circumstances, this article is focused on whether the concept of the smart city can be realized in the FIR era and how it could be realized in the digital economy. To address these questions, the role that smart cities can play in contributing to improvement of citizen's well-being and overall competitiveness is examined, and the question of whether smart cities can solve the multiple problems that global cities face at a global scale is explored. Finally, the socio-economic feasibility of building smart cities and the possibility of sustainable urban development is analyzed. This analysis employs various pragmatic research methods such as critical analysis of the literature, inference, and statistical data analysis.

Trajectory of the Fourth Industrial Revolution (FIR)

Background

The FIR was expected to start around 2020 with the development of artificial intelligence (AI), the Internet of things (IoT), big data, and advanced robots, all of which are core technologies of the FIR. Many scholars expect that the FIR, which is based on digitalization, will be accelerated due to the unexpected COVID-19 pandemic that began in 2020 and is ongoing in 2022. The pandemic is divided into three waves: health issues, economic issues, and the implementing process of the FIR. It is the latter that will impact our lives most significantly in the long run. The pandemic has resulted in the rise of telework as a new labour phenomenon that will change the organization of work time and which shows a clear trend toward expansion in the future [Bonilla-Molina, 2020; de Castro Sobrosa Neto et al., 2020; Walcott, 2020].

By using the core technologies noted above, the FIR enables two characteristics representing hyper automation and hyper connectivity. The former allows more advanced robots and AI to produce outputs, analyze results, and make complex decisions by adapting conclusions to given environmental factors. The latter is based on monitoring, analyzing, and digitalizing human-human, human-machine, and machine-machine connections. As a result, hyper automation can reduce the number of low and medium skill jobs that are highly repetitive and routine. Hyper connectivity enables universal, global, and almost-instant communication that opens the economic supply side. These two characteristics contribute to communications between and among governments, firms, humans, and machines, creating a cyber-physical system (CPS) connecting the technosphere, the natural world, and the human world [Gill, 2017; Stanford University, 2016].

Evolution of Industrial Revolutions

There are four distinguishable waves of industrial revolution, which can be explained by the concept of Kondratiev waves, or long economic cycles, connected with technology life cycles [Dicken, 2015; Park, 2018; WEF, 2016]. At the end of the 18th century, the first wave began with the industrialization of mechanical production using water and steam power. This resulted in mechanical innovations such as the steam engine, cotton spinning, and railroads. The second wave started at the end of the 19th century with the combination of electric energy and new production methods such as mass production and the division of labour. The key technological innovations in this wave were light bulbs, telephones, and assembly lines. Later, in the 1960s, the third wave began with the automation of production using electronics and information technologies as well as computing power that made cyber systems possible. It brought mainframe computers, personal computing, and the Internet. However, in the third wave it was not possible to combine physical and cyber systems due to limited technological capability.

In the 21st century, the fourth wave started with the use of AI, big data, IoT, advanced robots, and the ability to combine cyber and physical systems. The CPS changed production, making it cross-functional and interdisciplinary. It creates a far-reaching integration of production, sustainability, and customer satisfaction based on intelligent network systems and processes. In the fourth wave, digital collaboration is becoming very important in production and processes, while the efficiency of traditional hierarchical structures is declining and centralized decision-making processes in organizations are facing difficulty. The FIR will complete the global digital economy and will dramatically affect our daily lives, industry, society, and environment [Staffen, Schoenwald, 2016; WEF, 2016] (see Table 1).

Table 1. Historical Path of Four Industrial Revolutions

	Industrial Revolution	**Starting Year**	**Characteristics and Results**
Increase in Complexity	4.0	2020	Based on cyber and physical systems; AI, IoT, big data, and robotics
	3.0	1969	Based on electronics and information; technologies for automated production
	2.0	1870	Based on mass production enabled by electrical energy and division of labour; light bulbs, telephones, and assembly lines
			Based on mechanical production equipment

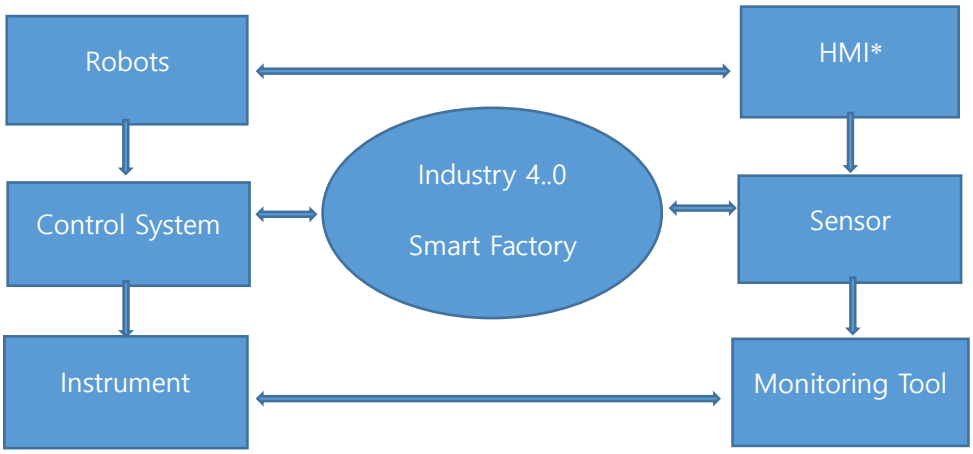
	1.0	1784	driven by water and steam power; steam engine, cotton spinning, and railroads

Source: Author's adaptation based on WEF [2016].

The FIR concept of Industry 4.0 was first used in 2011 at Hannover Fair, which was part of High-Tech Strategy 2020 in Germany. It was used as a collective term for technologies and concepts of value chain organization that create the CPS, IoT, Internet of services (IoS), Internet of people (IoP), and Internet of energy (IoE). The concept of Industry 4.0 is based on six design principles: interoperability, virtualization, decentralization, real time capability, service orientation, and modularity. These principles support companies in identifying and implementing Industry 4.0 technologies. The intention was to establish Germany as an integrated industry leader and market provider by redesigning manufacturing and production processes to create a fundamental shift from a centralized to a decentralized model based on the core information and communications technologies (ICT) systems. Accordingly, it is clear that the FIR set a path to digitalize not only German, but also European, industries [EC, 2016; Hermann, Pentek, Otto, 2015; Schlick et al., 2014].

There are three main characteristics of Industry 4.0: horizontal integration through networks to facilitate an internal cooperation, vertical integration subsystems within the factory in order to generate flexible and adaptable manufacturing systems, and engineering integration across the whole value chain allowing for customization of the product. Among these, horizontal and vertical integration are two basic building blocks for the engineering integration across processes. In this system, each component of the manufacturing process has its own intelligence and negotiating priority. This means that every component knows its location in the workflow and communicates with the facility by using IoT, IoS, IoP, and IoE. In the end, it requests to be processed with the method best able to minimize waste in production and to maximize customer satisfaction [Lom et al., 2016; Team VizExplorer, 2015] (see Fig. 1).

Figure 1. The Concept of Industry 4.0 and Smart Factory



Source: Author's adaptation.

* HMI – Human-Machine Interface

The real benefit of manufacturing in the FIR is that a component of a production system can call a smart service only when it is needed. As a result, all production processes are fully demand-oriented, and at the same time manufacturing resources are used only in the case of necessity. This means that the whole production process enables zero waste and resource-optimized conditions. Moreover, the smart manufacturing processes in the FIR provide smart services in real time that can minimize resources and at the same time maximize the use of existing infrastructures because the smart services can meet all requirements of demands [Lin et al., 2012; SAP, 2013; Schwab, 2016; Team VizExplorer, 2015].

Productivity will increase by 20% by using advanced analytics in predictive maintenance programmes. In Germany, the impact of Industry 4.0 can be estimated by productivity improvements on conversion costs ranging 15–25% excluding the cost of materials. As a result, additional revenue growth is estimated at €30 billion per annum, approximately 1% of German gross domestic product (GDP), and the new employment in manufacturing sectors is expected to increase by 6%. Furthermore, consumers in demand-oriented production processes can be more involved in the design process, which enables the final products to be made faster and less expensively than during the previous industrial revolution era. Thus, Industry 4.0 contributes not only to generating positive economic growth and new employment, but also to improving production processes and productivity. These positive impacts of the FIR will

spread continuously to the EU in time and eventually to the entire world, which is part of the EU's strategy for strengthening its competitiveness [EC, 2016; Park, 2018; Rüssmann et al., 2015].

The manufacturing industry has been regarded as the most important catalyst for technological innovation, economic growth, and prosperity in all countries around the world. In 2018, the total output of the global manufacturing industry accounted for 15.4% of the world's GDP. Most advanced economies generated and accumulated their economic growth and development during the early industrialization era. However, traditional manufacturing practices, along with organizational and business models, are facing severe challenges with the emergence of the FIR using the CPS platform and the new core technologies within the Industry 4.0 framework. Accordingly, the FIR will transform the global manufacturing industry fundamentally toward smart manufacturing mainly based on smart factories. As a next step, smart manufacturing, along with smart healthcare, smart transportation and smart energy systems, is expected to enable smart cities based on hyper automation and hyper connectivity, consolidating the final stage of the FIR [Suvarna et al., 2020; World Bank, n.d.].

Smart Environments

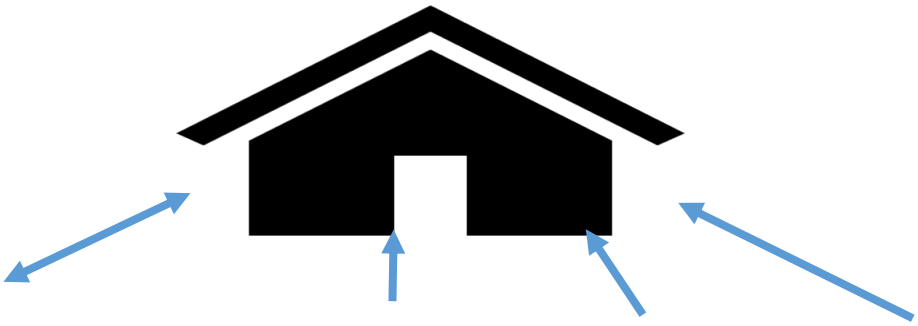
The convergence of communication and computing for mobile consumer devices has been on an evolutionary course to bring interoperability and to leverage services and function from every industry since the smartphone was introduced in 2007. In the process of convergence, the smartphone has been the leading device, playing the role of universal mobile terminal. As a result, it has become a common choice for consumers along with its use in business, although it was initially intended for business users only. Accordingly, the smart mobility established by the smartphone initiated the starting point of the smart environment in the 21st century by using functions of personal computers, including built-in cameras, applications for social websites, Internet browsers, wireless Internet, and much more [Sarwar, Soomro, 2013].

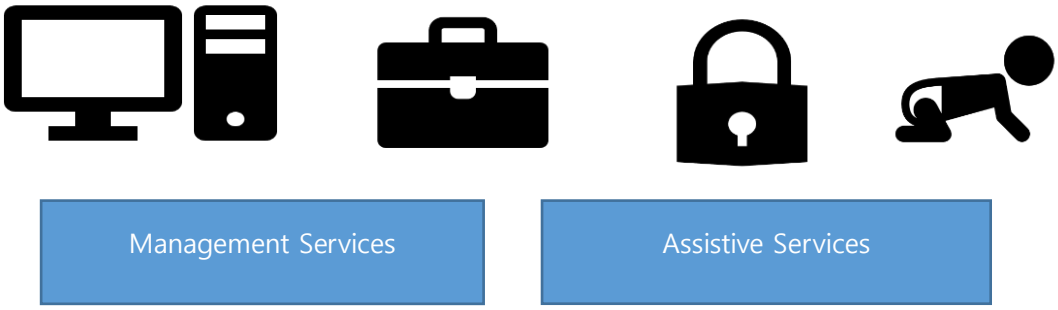
Additionally, smartphones provide their users the opportunity to exercise individual choice and improve their related self-efficacy based on their utilitarian nature, which has significant implications in most societies. As an example, smartphones created the citizen-journalist, using a camera phone and documenting on social media the demand for social and government change during the Arab Spring in 2011 and in several incidents of racism and discrimination in the U.S. in 2020 [Bajarin, 2020; Laprise, 2014].

The main features and services in key smart environments are based on smartphones, smart homes, smart factories, and smart cities, in sequence. These are the four vertical domains and each has distinct characteristics in terms of size and complexity, such as personal- vs business-oriented, single user vs multiple users, different objectives, and so on.

Smart phones are the first element of smart environments, connecting users to other devices controlling their daily life necessities and interacting themselves with other objectes. The second element of smart environments is the smart home, able to host technologies for interconnecting a large number of devices, providing the deployment of technological solutions and maintenance, and supporting useful services and applications for the inhabitants. Smart home services vary widely and are composed of assistive and management services. The former aim at providing direct support to users in their daily interests and activities, such as watching television, listening to music, setting of lights, and controlling multimedia devices. The latter provide specific functionalities such as for the security and safety of inhabitants, energy efficiency, and others [Castro-Jul, Díaz-Redondo, Fernández-Vilas, 2018; Gill et al., 2009; Gomez et al., 2019; Monacchi et al., 2017] (see Fig. 2).

Figure 2. Main Components of a Smart Home System





Sources: Author's adaptation based on C. Gomez et al. [2019].

The third element is smart factories based on a new business paradigm that generates benefits from the enabling technologies driving intelligent systems and environments. Smart manufacturing systems are able to make proper decisions to adapt and optimize production processes at runtime. At the same time, these can adapt to customers' personal preferences without any delay in the production processes. As a result, the proliferation of smart enabling technologies has initiated a digital transformation in the manufacturing industry that plays a crucial role in high productivity, zero waste production processes, and customer satisfaction in the digital economy. Such a paradigm shift is regarded as the FIR and the Factory of Future (FoF) [Karnouskos et al., 2012; Preuveneers, Ilie-Zudor, 2017].

Smart cities are regarded as the last step to realizing comprehensive smart environments in the FIR. They provide one of the richest and most complex scenarios for smart environments and include several domains, such as the environment, economy, mobility, energy, planning, and governance, among others, presenting various challenges and multiple actors, such as city administrators, operators, service providers, citizens, and possible competing objectives. Furthermore, building smart cities is not a technological challenge, but diverse and heterogeneous challenges (environmental, safety, and security) can confront citizens and cities even while smart cities work to develop better urban systems to improve the quality of life. ICT technologies are often transversal across all domains and challenges so that they are able to plan a number of scenarios for smart cities from e-tourism, e-culture, e-health, e-government, smart energy, smart mobility, and many others. These constitute the global mega trend of the FIR in the digital economy that many governments around the world are pursuing [Gomez et al., 2019] (see Fig. 3).

The heterogeneity of technical problems and of available technologies linked to political issues is the most significant barrier delaying the development of smart cities. To overcome this barrier, the interoperability of technological solutions and standards is of the utmost importance, particularly in the field of IoT, which is widely recognized as the key technology to build smart cities. In a recent trend, novel participatory sensing and paradigms are being introduced, in which citizens are involved in the task of sensing data from the smart cities by using mobile applications for their smartphones [Castro-Jul, Díaz-Redondo, Fernández-Vilas, 2018; Zanella et al., 2014].

Figure 3. Smart Cities' Most Relevant Domains

Source: Author's adaptation based on Gomez et al. [2019].

Smart Cities in the Fourth Industrial Revolution

Global Development Trend of Smart Cities

The amount of digital information created and replicated, referred to as the digital universe, has increased rapidly. It grew from 1.2 million petabytes in 2010 to 33 zettabytes in 2018. It is expected that the digital universe, by 2025, will grow to 175 zettabytes, reflecting an average annual growth rate of 61% in 2010–25. Additionally, connectivity is also rapidly growing, increasing from 1.9 billion Internet-connected devices in 2013 to 9 billion devices in 2018. Such a high growth in data and connectivity makes it possible to gather, analyze, and use real time information, which influences public policy and improves the quality of life, through the services used by ICT. [Patrizio, 2018; Reinsel, Gantz, Rydning, 2018].

Despite the reality, some still believe that smart cities remain conceptually vague and undefined. However, it is generally understood that the use of new technologies and data platforms has improved the functioning of cities, and concrete policies and practice shifts have been deeply involved. Therefore, implementation and adoption of smart cities will create a paradigm shift in which cities commit not only to using new technology for increasing their efficiency but also to changing their policies and operating procedures to support their goals [NLC, 2016].

Across history, cities have been ever-changing, and the dynamism of the urban environment can be regarded as a microcosm of societal interactions. Technology has always been a critical force deeply intertwined with the evolution of cities. In the FIR era, cities will evolve into smart cities offering solutions to many different problems. They involve various actors, such as those from the public, private, and non-profit sectors, which form partnerships and cooperate to improve city life through innovation. The emphasis on innovation makes the definition of smart cities subject to change because the technology used in smart cities is often new or evolving and prone to rapid change and development. An automated urban development in Songdo, Korea in 2009, supported by Cisco Systems using the technology of radio frequency identification (RFID), represents one example. RFID was considered outmoded after smartphone use increased rapidly in 2012. It was a serious mistake to adopt the outmoded RFID technology in the Songdo Smart City, including to build the Songdo International Business District, which struggled to return to the right track. The smart city project was estimated to have cost $40 billion and could result in severe economic loss to the city government if it fails [Cluster Urban Regional Development, 2020].

In addition to adopting the latest technologies, smart cities must develop smart programmes and make paradigm shifts to consider how to initiate and govern those programmes, address concerns about their citizens, and cope with a rapidly changing environment. To understand the trend of smart cities, it is important to look at various case studies to see how they are organized, structured, and administered, and how the community has been engaged in their development and implementation. Smart cities take many different approaches to solving the problems they face, and there is no one-size-fits-all way to adopt and implement smart city systems. This means that all smart cities must solve public problems based on their own solution measures, which may serve as an example for other smart cities [NLC, 2016].

In the 21st century, smart cities are not regarded as infrastructure, but rather as data. Therefore, they are an evolved model of cities, creating a connection between the city and its citizens in which the city is not seen as a physical space, but as the centre of citizens' participation. This means that smart cities can be seen as platforms evolved from data platforms, enabling reduced costs and creating values for citizens. These are the ultimate objectives of smart cities. In pursuit of these, major global cities are following the digital twin strategy, where the real public problems of the real city can be solved in the virtual city using the process of smart transformation. This is the new global trend of development for smart cities [Cohen, 2015; Eggers, Skowron, 2018; Lee et al., 2018].

Global Trend of Smart City Policies in Major Countries

A key question is whether investment in smart technologies and digital innovations ultimately contributes to improving the well-being of citizens and generating sustainable development. It is the most important concern regarding the implementation of smart city policies in major countries in the world. Despite the various concepts of smart cities, a human-centric approach is regarded as the key factor to make a city smarter. Therefore, smart city policies must focus on the following four issues; first, improving quality of life and delivering solutions; second, stakeholder engagement in local governance and collaborative partnerships; third, public access to open data and collaboration between all stakeholders; finally, integrated and holistic approaches to address urban challenges [OECD, 2020].

The planning and building of smart cities have been particularly driven by the strong demand for urban

development in China and India, and it has spread worldwide. In fact, the promotion of smart cities in major cities has been possible with the development of AI technology, represented by deep learning and platform companies. With the rising trend of smart cities around the world, major countries in Asia, Europe, and North America have started to develop smart city policies in their urban development strategies [Yun, Lee, 2019].

In Asia, smart cities are regarded as a new strategy to improve the competitiveness of cities as global cities and revitalize their urban economies because the construction of new cities is the main factor. As a major strategy for its smart cities, China has actively used AI technology, and its Ministry of Housing and Urban Development (MHUD) announced the first list of national pilot smart cities in 2013. Since 2014, the MHUD has promoted close to 500 smart cities pilot projects. Korea is the pioneering country in Asia when it comes to developing science cities. In 2009, Songdo City was built as a ubiquitous city solving city problems using ICT technology. The Smart City Initiative (SCI) was launched in 2015 to establish and spread the Smart City Integrated Platform. As a result, smart cities in the second largest city, Busan, and the new administrative capital city, Sejong, were constructed as pilot projects in 2018. The Korean SCI has been highly successful thanks to a high level of smartphone users (over 95% of the total population), compact urban development, the development of the IT industrial ecosystem, and rising local governments' initiatives. Moreover, the national government is rethinking how to live smart in a digital era, while facing three main concerns about privacy, smart divide, and cost [ITU, 2013; OECD, 2020].

Japan has also been active in building smart cities; the government launched the New Growth Strategy in 2010 and identified the Future City Initiative as one of its national strategic projects. In 2016, the government upgraded its smart city policies with the Future Investment Strategy, in which Society 5.0, known as the Japanese version of the FIR, was suggested as a blueprint for future smart cities. In building its smart cities, Japan intends to comprehensively develop healthcare, mobility, supply chain, city infrastructure, and fintech. India is another major country to build smart cities, launching its Smart Cities Mission in 2014 and 2015. In the mission, the Ministry of Housing and Urban Affairs (MHUA) announced 100 smart cities across the state. Singapore, as a city state, has carried out the digital twin strategy to solving public problems by using ICT. In 2015, the government initiated Infocomm Media 2025 and focused on establishing a smart state platform for sustainable and quality growth and better quality of life. Carrying out the digital twin strategy, Singapore created Virtual Singapore. Overall, all Asian countries have carried out their smart city policies based on three characteristics: government leadership, increased city competitiveness, and economic revitalization [Cabinet Office, 2021; Liceras, 2019; Smart Cities Mission, 2021].

In North America, the U.S. plays a leading role in building smart cities. In the U.S., a smart city industrial ecosystem has been formed largely by private companies. The government has mainly supported initiatives of private companies to establish industrial ecosystems for smart cities by launching the Strategy for American Innovation in 2009 and the Smart America Challenge in 2013. Furthermore, the government invested over $160 million in federal research and leveraged more than 25 new technology collaborations with the Smart City Initiative in 2015. Two years later, the Department of Transportation carried out the Smart City Challenge programme to build a smart transportation system that would use data, applications, and technology to support the movement of people and goods. The U.S.' smart city policies are private sector-led, mobility- and energy- oriented, and focused on high value-added industry [U.S. Department of Transportation, 2021; Yun, Lee, 2019].

In the EU, all governments have focused on the environment and transportation in their smart city policies. In 2010, Europe 2020 was launched for smart, sustainable, and inclusive growth and a year later the European Innovation Partnership was built for smart cities and communities focusing on energy, transportation, and ICT. Moreover, the strategic implementation plan of the Partnership for Smart Cities and Communities was introduced at the Smart City Conference in 2013, and financial instruments for urban development were decided with a minimum €16 billion over the period 2014–20 in Horizon 2020. Additionally, the EU launched the WiFi4EU Initiative providing municipalities with vouchers up to €15,000 to become open data connected. The main characteristics of the EU's smart city policies are unique compared to Asian countries and the U.S. in that they are public-private cooperation-centred, environment- and mobility-focused, and open data-connected [EC, 2021] (See Table 2).

Table 2. Smart City Policies in Major Countries in the World

Countries		**Tools of Policies**	**Characteristics of Policies**
Asia	China	National pilot smart city (2013) 500 smart city pilot (2014)	Government-led, city competitiveness-oriented, economic revitalization-
	Korea	Ubiquitous City (2009), Smart City Initiative (2015), Smart Cities Pilot Projects (2018)	
	Japan	New Growth Strategy (2010), Future Investment Strategy (2016)	

	India	Smart Cities Mission (2014, 2015)	focused
	Singapore	Infocomm Media 2025 (2015)	
U.S.		Strategy for American Innovation (2009), The Smart America Challenge (2013), Smart City Initiative (2015), Smart City Challenge (2017)	Private-led, mobility- and energy- oriented, high value-added industry-focused
EU		Europe 2020 (2010), Smart City Conference (2013), Horizon 2020 (2014), The WiFi4EU Initiative (2018)	Public-private cooperation-centred, environment- and mobility-oriented, open data-connected

Source: Author's adaptation based on Y. J. Yun and M. H. Lee [2019].

As pointed out above, approaches to smart city policies vary from region to region based on historical, cultural, economic, political, and social targets. In Asia, developing countries such as China and India are keen to develop smart cities in order to overcome hurdles in their hyper urbanized mega cities using digital technologies and to achieve high economic growth. Developed states such as Japan, Korea, and Singapore focus on creating smart cities to prepare for the FIR era and to increase their global competitiveness to attract domestic and international residents. Therefore, their strategies are strongly driven by the government. By comparison, the U.S., led by its private sectors, intends to build smart cities to develop high value-added industrial sectors in already built modern cities. The EU focuses on the sustainable development concept based on the partnership between smart cities and communities. Accordingly, public and private cooperation in the EU context seems to be crucial.

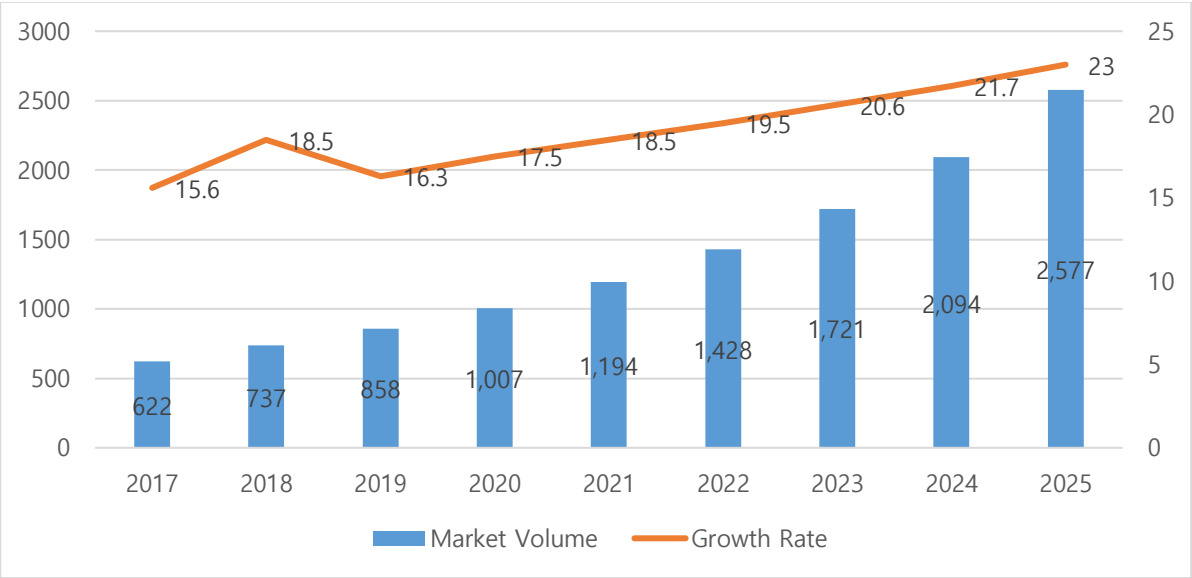
Smart Cities as a New Global Market

The development of smart cities enabled by digital technologies is regarded as one of the most important social achievements in the 21st century. In fact, smart cities are not an isolated phenomenon but are rather an integral part of a broader transition toward a digital economy, which causes big and fundamental shifts in value propositions, customers, channels and relationships, activities and resources, partners, and costs and revenues. A fundamental difference between the digital economy and the physical economy is the widespread availability of free content and services. This means that a part of all values created by the digital economy is paid for by users, and industry generates revenues by advertising, data, and additional services. Accordingly, smart cities providing data and services are a rising industry in the digital economy of the 21st century [Deloitte, 2015; Popkova, Ostrovskaya, 2019].

The development of smart cities around the world has accelerated since the 2010s. The global smart city market accounted for $622 billion in 2017 and $737 billion in 2018, an increase of 18.5%. The total value of the global smart city market was projected to exceed $1 trillion in 2020 and $2.5 trillion by 2025. Other market research, such as that conducted by Persistence Market Research, more optimistically predicts revenue up to $3.5 trillion by 2026. The average growth rate from 2018–25 is estimated at 19.5%. The smart infrastructure segment was overwhelmed in the overall smart cities market share in 2017 because of the significant adoption of security and transportation solutions among its users. In addition, smart energy may have the highest growth rate from 2018–25 [Grand View Research, 2018; Kumar, Borasi, Kumar, 2018; PWC, 2019; Smart Cities Association, 2021] (See Fig. 4).

Rapidly increasing urbanization worldwide has entailed the need for smart cities. Furthermore, government initiatives and funding for research and development (R&D) activities around the world have significantly diversified the demand for building smart cities. At the same time, development of new ICT such as IoT, AI, big data, and cloud computing has strengthened the smart cities concept, and the high speed of internet connectivity has also played a vital role in developing the smart city industry. In that industry, hardware components and software solutions play an equally important role in market development, which has seen a rapid growth rate of over 20% on average per year during the forecast period. The hardware segment by component is projected to be even higher than the average growth rate. Furthermore, the development of new technologies in electric vehicles (EVs) and renewable energy systems could substantially contribute to building smart cities; technology proliferation boosts growth prospects, providing high benefits to city infrastructure stakeholders. Therefore, most governments around the world are keen to invest in the smart city mission in order to create economic growth and enhance the quality of life of people in urban areas [Grand View Research, 2020; Market Research Future, 2017].

Figure 4. Estimate of the Global Smart City Market's Growth Rate and Volume, 2017–25 ($ Billions)



Source: Author's adaptation based on Grand View Research [2018] and Persistence Market Research [2017].

In 2017, North America, particularly the U.S., dominated the overall global smart cities market due to its significant adoption of smart cities' solutions supported by highly developed ICT, which was financed by government organizations. The smart city projects in Chicago, Philadelphia, Charlotte in North Carolina, and San Francisco represent this trend. At the same time, a high demand for connected solutions across the region existed. Similarly, the smart cities market in the EU is also expected to grow at a significant rate because the EU focuses on energy and climate objectives to tackle the tasks related to global climate change. Therefore, all members will implement the distribution of energy with efficient models and strategies to meet the target of the low carbon economic system, aims to achieve a carbon neutral economic system by 2050. Along with North America and Europe, smart cities in the Asia Pacific region are expected to grow to the highest level in the world during the forecast period as Asian governments are increasing their IT spending rapidly and taking initiatives to carry out pilot projects to build smart cities, particularly in the Arab Emirate Republic, China, India, Japan, Singapore, and Korea [Kumar, Borasi, Kumar, 2018; NLC, 2016; Smart Cities Association, 2021].

The COVID-19 pandemic also strongly impacts the smart city market. Many governments have already deployed smart city technologies to fight against the pandemic by tracking the spread of the virus and implementing medical strategies. In practice, several smart cities have used smart city platforms and various technologies, such as heat maps, global positioning systems (GPS), and aerial surveillance systems to monitor COVID-19 patients. Furthermore, many smart cities have adopted advanced contact tracing systems, gathering data from various sensors and cameras to reduce the infection rate and avoid lockdown situations, which have had significant, negative economic impacts. Integrated data governance on a smart city platform can facilitate rapid, evidence-based decision-making at an urban scale. At the same time, data access is also promoted in smart cities, focusing on the wide dissemination of data. As a result, citizens can be engaged with data governance so that people living in areas with diseases like COVID-19 who fall ill can be identified as quickly as possible [Kumar, Borasi, Kumar, 2018; Market Research Future, 2017].

Rapid urbanization across the globe is a key driver for the significant market growth of smart cities. Despite the promising growth trends, however, the smart cities market still faces various challenges. First, the high costs associated with the implementation and maintenance of components could slow market growth. All smart city systems comprise various, highly sophisticated devices and solutions that involve high expenditures and regular maintenance. Therefore, innovative smart cities require specific funding mechanisms, including partnerships with private companies, smart procurement policies, and national or local level funds. Moreover, the lack of expertise and proficiencies among users is also a major challenge. Teaching citizens in smart cities how to navigate the digital world is an important task that governments need to support with continuous digital skills training [Market Research Future, 2017].

Analysis of Smart Cities

Benefit and Effectiveness

After a decade of experimentation, smart cities have now entered a new phase. To make smart cities great, digital solutions are the most powerful and the most cost effective. By adding digital intelligence to existing urban systems, smart cities enable their citizens to make better decisions. In smart cities, smart applications in eight domains, namely,

mobility, security, healthcare, energy, water, waste, economic development and housing, and engagement and community, have affected multiple aspects related to quality of life. They have made smart cities more efficient, responsive, and sustainable [Woetzel et al., 2018].

Each sector contributes its own unique innovation to improving smart cities. In mobility, lower congestion and pollution through optimal use of transportation infrastructure is possible, while the public safety threats can be quickly responded to through the use of real time analysis of sensor and surveillance camera data. In healthcare, better diagnostics and personalized treatment through AI based on a massive volume of patient data are fully possible. Moreover, energy savings through real time insights on energy use, more efficient waste collection through sensors, and optimal water distribution based on the analysis of data, can be implemented. Increasing efficiencies in energy savings, waste collection, and water distribution can also contribute to mitigating global climate change. Last, new forms of digital democracy and participatory government based on co-creation of decision-making are a reality in smart cities [Deloitte, 2015].

The core technologies of the FIR such as AI, big data, blockchain, IoT, and advanced robots may allow for reduction of economic costs in smart cities. At the same time, the new technologies create smart cities as platforms generating network effects that are responsible for 60% of GDP as principal agents of production. In the network effects of platforms, benefits of smart cities are expected to grow exponentially, while cost effects can be optimized and minimized in the digital economy era [Bouton et al., 2013; Yun, Lee, 2019].

Various analyses on the effectiveness of global smart cities have been conducted by academics, private companies, and research institutes. To examine the effectiveness of smart cities, three analyses focusing on their benefits, from a scholar, a global company, and a research institute, are considered. MGI, a global economic consulting institute, chose three smart cities as samples to assess how dozens of smart city applications could perform with varying legacy infrastructure systems and baseline starting points. The outcome of the assessment is that smart cities can use them to improve quality of life indicators by 10–30%. More specifically, 30–300 lives could be saved each year in a city of 5 million people, while 30–40% of crime incidents could be prevented. In healthcare, an 8–15% reduction in disease could be obtained, and 15–30 minutes could be shaved off the daily commute on urban transportation. In water consumption, 25–80 liters could be saved per person per day. Additionally, a 20–35% improvement in emergency response times could be obtained, while social connectedness and civic participation with local governments could increase by up to 25%. The cost of living could decline marginally by 1–3% and formal employment could increase slightly by 1–3% [Woetzel et al., 2018].

In Asia, the global internet company, Alibaba Cloud, also confirmed that the Chinese smart city, Hangzhou, could reduce average commuting times by 15.3%. Another study, carried out by G. B. West, an academic, supported a positive view of the effect of smart cities. He demonstrated that the cost of infrastructure in smart cities could be reduced by 15% due to the network effect. Although these two studies did not cover the full effects of smart cities comprehensively, as MGI did, it is clear that smart cities can contribute to reducing average commuting times and construction costs by using smart city platforms. Smart cities are expected to become self-organizing cities with the optimal production and consumption structures. At the same time, they can generate benefits continuously by using their platforms and network effects. Smart cities will ultimately be a major industry of the FIR in the future that will account for over 15% of global GDP [Smart Cities Association, 2021; West, 2017; Yun, Lee, 2019; Caprotti, Liu, 2022] (See Table 3).

Table 3. Analysis of Benefits of Smart Cities

Character	Research Institute (MGI)	Global Company (Alibaba Cloud)	Academic (West)
Benefits	- Increase quality of life by 10–30% - Decrease crime incidents by 30–40% - Improve health care by 8–15% - Reduce daily commuting time by 15–30 minutes - Reduce water consumption per person and per day by 25–80 liters - Reduce emergency response time by 20–	- Reduce commuting time by 15.3%	- Reduce cost of infrastructure by 15% - Generate

	35% - Increase social connectedness and civic participation by 25% - Reduce cost of living by 1–3% - Increase new employment by 1–3%		network effects

Source: Author's adaptation based on Woetzel et al. [2018], Caprotti & Liu [2022], and West [2017].

Challenges, Problems, and Risks

Smart cities do not only generate benefits but also various challenges, problems, and risks that are regarded as environmental, physical, socio-economic, and political costs. One of the challenges is the imminent disruption of the labour market because progressive automation and use of robotics will substantially replace manual work. Attracting a talented workforce is also a challenge closely linked to the disruption of the labour market and at the same time related to the demand and supply side of highly educated workforces. Maintaining social cohesion, inclusiveness, and solidarity are other challenges because the benefits of smart cities cannot cover all groups in societies equally. Security and privacy are also important issues to tackle as societies become more vulnerable to cybercrime using Internet-connected data. Last, but not least, resilience of digital infrastructure and smart solutions is also a significant challenge. If vital digital infrastructures fail or are attacked, serious disruption of society and economy could take place. These challenges must be overcome and properly handled. Otherwise, smart cities will face difficulties affecting their further development [Deloitte, 2015; Florida, Mellander, King, 2015; Schwab, 2016].

Along with these challenges, several problems and risks are linked to the development of smart cities. From a technological perspective, the growing ubiquity of the smartness trend increases the exclusion of conventional methods of problem-solving and marginalizes critiques of the status quo. The core technologies in the FIR era can facilitate economic prosperity, well-being, urban liability, and even social justice. However, the positive impacts of these technologies can only be realized if the right complements, such as well-thought-out policies, mature institutions, and capable and responsible governance, are combined. Therefore, analog and conventional assets should not be neglected [Green, 2019; Offen, 2015].

Moreover, several scholars argue that citizens represent different interests and needs, but that these are rarely stated in the discourse around smart cities. It is, therefore, crucial that scholars, professionals, and citizens at large, representing a wide range of communities and perspectives, are able to participate in the discourse for building smart cities in order to create more inclusive spaces. Additionally, it is noteworthy that smart cities based on various technological business models and features can generate other social problems and risks such as infrastructure sustainability, privacy protection, extremism, polarization, misinformation, and Internet addiction [Ahmad et al., 2021; Engelbert, van Zoonen, Fadi, 2018; Listerborn, Neergaard, 2021] (See Table 4).

Table 4. Analysis of Challenges of Smart Cities

Characters	Socio-Economic and Political Costs
Common Challenges	- Imminent disruption of labour market based on automation - Difficulty of attracting a talented workforce - Weakening social cohesion, inclusiveness and solidarity - Increasing cybercrime - Serious disruption of society and economy by attacks on digital infrastructure - Reducing relatively low living costs - Generating relatively low new employment
Problems and Risks	- Exclusion of conventional methods of problem-solving - Inequality - Infrastructure sustainability - Privacy protection - Extremism, polarization, misinformation,

	and internet addiction

Source: Author's adaptation based on Ahmad et al. [2021], Deloitte [2015], Engelbert et al. [2018], Florida et al. [2015], Green [2019], Offen, [2015], Listerborn and Neergaard [2021], and Schwab [2016].

Conclusion

The Fourth Industrial Revolution, characterized by hyper automation and hyper connectivity driven by advanced technologies such as AI, IoT, big data, and advanced robots, is either imminent or already upon us. Officially, the World Economic Forum (WEF) declared that the FIR would begin by 2020, so we must already be in its initial period. The process of the FIR was accelerated because of social distancing and the lockdown of communities and cities across the world due to the COVID-19 pandemic. We have been testing these technologies in our daily lives, such as home office work, online lectures, and conferences, more than ever in order to overcome the restrictions imposed by the pandemic. In doing so, we often seem to be confused as to whether we live in the physical world or in the cyber world. The pandemic has ushered in the FIR faster than we have expected.

As discussed, the FIR has its own trajectory and processes such as smartphones, smart homes, smart factories, and smart cities. Therefore, most governments across the world have initiated smart city projects and launched various pilot projects to build smart cities competitively to realize the FIR as early as possible in their own countries. North American states, particularly the U.S. and Canada, began to launch pilot projects for smart cities in early 2000s, and the EU as well, as Asia followed the same trend in the mid- to late 2000s. Regions seek to build smart cities according to particular characteristics but their goals are the same: to strengthen the competitiveness of smart cities and provide their citizens a better quality of life by solving urban problems with ICT technologies in the digital economy.

Smart cities based on these core technologies are regarded as the end-product and the comprehensive service provider for inhabitants in urban areas in the FIR era. They could solve many problems and improve services that most traditional and conventional cities cannot deliver. AI, IoT, big data, advanced robots, and blockchain technology can connect, interact, and communicate with all the stakeholders in a city. As a result, they can reduce commuting times, urban and cybercrimes, waste, water and energy consumption, as well as save more lives. Additionally, local government and citizens can be more interactive in order to improve administrative services by the active participation of citizens in the decision-making process, both online and offline. Overall, smart cities enable improvements in their services by an average of 10–30% and reduce infrastructure costs by an average of 15%. These are ultimately tangible benefits of smart cities, which all governments want to create and develop. Moreover, smart cities are expected to play positive roles in the urban environment in general and to mitigate global climate change, in particular, by using core technologies in the FIR that enable optimization of all kinds of energy consumption, production, and services.

However, smart cities are not safe havens, avoiding all the problems, difficulties, and risks we experience in our daily lives. They still face various challenges, problems, and risks that generate socio-economic, political, and social costs, represented by disruption of labour markets, digital discrepancies, threats to social coherence and inclusiveness, privacy protection, inequality, misinformation, polarization, and so on. Furthermore, the high initial costs of digitalizing all infrastructures in smart cities could burden finances, particularly in countries in emerging markets, which plan to build and develop smart cities.

Despite these challenges, there is no doubt that smart cities will play a significant role in the digital economy and create a rapidly growing industry. The global market volume for smart cities is expected to increase to $2.5 trillion by 2025 and the share of output in global GDP is expected to increase to 15% in the future. This means that the digital economy could reach an epochal turning point, and smart cities may play key roles in the digital economy in the FIR. Overall, as smart cities become realities, we will see whether they will optimize our daily lives or if they instead will generate negative impacts. Their longer-term outcomes remain to be seen.

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