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Regional Smart City Development Focus: The South Korean National Strategic Smart City Program

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ABSTRACT Cities around the world are interested in using information and communications technology to solve their urban problems. The smart city concept has been widely adopted as a solution, but the range of services offered in smart cities varies by city and region. The differences are due to a variety of factors, including urban characteristics, social needs, and governmental structures. In Korea, the National Strategic Smart City Program (NSSP) was launched to establish a new technological ecosystem and standards for smart cities. In this study, we introduce the smart city services being developed by the Korean NSSP and compare them to services offered in 15 smart cities in Europe, Asia, and North America. The NSSP services are characterized by applications of 5G telecommunication technology and the definition of its data structure. These characteristics are unique; unlike other existing smart city policies, the NSSP aims to widen the industrial territory of the smart city itself. In conclusion, smart city policies in recent years include measures for not only making cities sustainable but also creating prospective industrial areas, which requires cooperation with public information and construction systems.

INDEX TERMS National Strategic Smart City Program, research and development, smart city, smart city services.

I. INTRODUCTION

An increase in urban populations and city complexities creates challenges in the areas of transportation, the environment, energy, and social cohesion. The smart city concept has emerged as a technological solution to these problems. Although similar concepts have existed for more than a decade [1], [2], a new technological transition (including wireless communication and artificial intelligence) has enabled smart city applications to become more powerful and diverse. Therefore, smart cities are expected to become promising business plans in the near future.

Since each city in the world has different environments and urban problems, the definitions of smart cities to solve these problems are also emerging in various forms. Some definitions rely on key values of smart cities (such as sustainability or democracy), others rely on their measures (such as data structure or organization), and others look to their service components (such as smart transportation or smart infrastructure) for a definition [3], [4]. In 2016, a report by the United Nations Economic and Social Council (UN-ECOSOC) [5] claimed that the definition of a smart city is unclear and diverse needs for development should be understood. In recent times, international standards have been developed for smart cities (ITU KPIs, ISO 37122), but these standards remain a technical listing of existing definitions. In short, the objective and reality of smart cities is still too ambiguous to be clearly defined, and the relationship between the domains of a smart city is undeveloped.

Another problem of a smart city discussion is the lack of empirical substantiation on their effects. Every smart city claims that it is environmentally sustainable and free from traffic congestion, but its actual effects are too difficult to

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measure. In the case of carbon emission, no significant difference was found between smart cities and other cities or their ''less smart'' past [6]–[8]. Therefore, ''smart city'' is often used to describe a panacea for urban problems, and specific effects or objectives have not been well communicated to the public. Still, developing a smart city concept is necessary despite the ambiguity of current smart city discussions. Society is expected to change due to revolutionary improvements in information and communication technology such as deep learning, autonomous vehicles, and 5G telecommunications. The application of technology in cities is not the only requirement; cities themselves need to adapt to the upcoming technologies to mitigate the social impact of changes.

In Korea, the concept of smart cities has been discussed for a couple of decades, and has faced the abovementioned problems. In the 2000s, the Korean smart city model of ubiquitous city (U-city), a city where people and things can access the Internet anywhere and anytime, developed. The U-city model focused on building high-speed Internet connections as part of the decade's development trend for large-scale new towns. Songdo International City is a representative model of this kind of development and has received global attention. However, the U-city is largely focused on telecommunication infrastructure, not on real-world services, so citizens do not actually experience what the ''smart city'' provides [9]. In the 2010s, as population and economic growth slowed, Korean smart city strategies changed. Smart city development in the 2010s was more focused on providing various city services, rather than on hard infrastructure. Instead of investing large amounts of governmental resources into services, municipalities led small-scale developments of individual smart city services. Still, the services were driven without any integrated system or specialty thus smart city initiatives could hardly be sustained.

In recent years, Korean cities have experienced problems such as fine dust, energy inefficiency of old buildings and infrastructure, aging populations, traffic congestion, large-scale disasters in cities, and the inefficiency of administrative services. In 2018, the Korean government planned a new nationwide project for developing source technology for smart cities. The National Smart City Strategic Project (NSSP) is a research and development project, which involves mobile carriers, technology-centered SMEs, research institutes, and local governments. While mobile carriers facilitate an information platform, SMEs and institutes have developed elemental technologies and municipal governments have provided regulatory support to demonstrate the new services. The main goals of the project are as follows: (1) to develop an integrated data platform for a smart city (2) to develop and apply source technology for city services, and (3) to foster enterprises and develop a market in smart city industries. According to this strategy, the NSSP can be a solution for existing smart city problems. At the same time, the project is used as a means for national economic development. Regardless of whether the project will progress well, the Korean NSSP model can be a new model for smart city development.

This study focuses on the new development project of the Korean NSSP in comparison to existing smart city services. Cities in various countries have planned and developed smart city services for over a decade. These cities have different historical, demographical, environmental, economic, and political backgrounds, and smart city development has been driven by different organization and strategies. Understanding this difference is necessary to evaluate the Korean case from an objective viewpoint. On the contrary, the study will focus on the purpose of the project, which regards smart city development as an economic opportunity to nurture new key industries for the future. Rather than just developing a good city for residents, the Korean government is investing in the development of new technologies for smart city industries.

This paper introduces the Korean National Strategic Smart City Program, which was planned in 2018 and is now in progress. The main focus of this study is an analysis of the project's smart city services against a systemically developed framework. The framework was developed through a review of smart city service coverage in 15 leading smart cities globally. In this context, this study aimed to explore the focus of Korean smart city R&D projects. Furthermore, implications for future smart city development are suggested according to regional differences and global smart city trends.

II. BACKGROUND

A. SMART CITY LITERATURE

Since the smart city concept is fairly new, most existing studies have been conducted recently, and cases from diverse countries and cities have been examined. Therefore, there are a variety of conceptions of what a smart city is. Recent studies of smart cities can be divided into four types.

First, there are studies that have analyzed the characteristics of individual smart cities being developed worldwide and include cities in developing regions such as East Asia, Southeast Asia, Middle East Asia, Africa, and Central America. For example, studies on smart cities in Europe have mainly focused on how to solve the urban problems of existing cities with smart city technology [3], [10]–[16]. In this case, research has explored ways to rank smart cities in Europe [3], [10], how to make existing cities ''smarter'' [11], [12], [14], and how to provide benefits to citizens using smart technology [13]. Smart city cases in developed countries are different for each region [17], and studies focusing on developing countries have recently shown that smart city development in China [18]–[22], the Middle East [23], [24], and Southeast Asia [25], [26] have adapted various technologies for their new town developments. In addition, research has been conducted in Singapore [25], Australia [27], and South Korea [28], as well as in developing countries such as India [29], [30], some African nations [31], Brazil [32], and others [33]. Such countries are usually in the process of building new cities. Therefore,

TABLE 1. Research theme category and main contents.

Research theme	Contents
The concept of a smart city	- Smart city concepts, urban planning theories, discursive approaches, smart city implementations
Characteristics of smart cities	- Smart city rankings, solutions for urban problems, new town planning, building and infrastructure, promotion of tourism, city expectations, role of citizens and public sector (focusing on each country and city's goals and benefits)
Elements of smart cities	- Computer science, big data, electronic government, virtual reality, education services, resilience, the sharing economy, environment, tourism, development, security, food supply, transportation systems, wireless sensors, IoT, water management
Methods for smart cities	- ICT companies, smart government, public service ranges, smart applications, university participation, governance, planning support systems, technology providers

when creating new infrastructure or urban developments, it is necessary to consider efficiency [19], the promotion of tourism [24], city extensions [25], and the role of the civilian and public sectors [26]. In addition, the smart city concept has become a new model for regenerating brownfields. In developed countries, cities can manage pressing urban problems without developing new undeveloped land [34]–[36]. Country-specific smart city case studies offer diverse models of smart city development but reflect only the characteristics of the cases; therefore, defining what a smart city is differs from what strategies can be used to implement one.

The second type of research analyzes the common elements of smart cities. These are studies of the elements of technology and unit spaces utilized in a smart city. Furthermore, this kind of research deals with such subjects as computer science, big data, governance [37]–[40] key performance indicators [41], [42], virtual reality [43], [44], education [45], resilience [46], sharing economies [47], environment [48], tourism [49], development [50], security [51], food supply [52], transportation systems [53], [54], wireless sensors [55], data and services [56], [57], ecosystems [58], energy management [59]–[63], the Internet of Things (IoT) [64], and water management [65]. This is the case with studies that demonstrate how smart city technology is applied to almost all city components. However, a comprehensive approach to these technologies is limited to examples from specific cities.

Third, there are studies of the methods for creating smart cities and examples of the development of these smart cities by high-tech companies. Other subjects covered in these studies include smart city cases promoted by leading information and communications technology (ICT) companies such as IBM [66], [67], smart city cases driven by government policies [68], smart city service ranges [69], applications of the IoT [70]–[74], the role of universities [75], and the relationship between participants [76], [77]. There are also studies dealing with the scale of smart cities [78], [79], planning support systems [80], [81], and the smart city technology provider's relationship with citizens [82], [83].

Finally, there are comprehensive studies which examine all variations [42], [84]–[89], apply urban theory and discursive approaches [6], [7], [90]–[99], and compare the implementation of smart city concepts across different city categories [100]–[103]. These studies provide a comprehensive coverage of smart cities by utilizing conceptual approaches. However, few studies have utilized a comparative approach for studying the ways in which smart cities are implemented in different countries (Table 1).

This study compares the differences between the South Korean strategies of promoting smart city planning and those of countries across the world; it differs from existing studies in that we adopted a systemically categorized framework and reinforced this framework by investigating the latest global smart city services. In addition, this study is novel in terms of defining the type of smart city services in South Korea among these categories. The studies that have conducted comparisons between smart cities will be introduced in chapter B below. These studies have created their own categories but have limitations regarding the development of smart city technology in South Korea that cannot be described here in detail.

B. SERVICE DOMAINS OF SMART CITIES

The researchers investigated the existing classifications of smart city services and established a comprehensive framework for analysis based on commonalities in the service domains identified in the literature. In Table 2, six representing studies and two international standards are shown with the services classified into 5–7 domains. Based on these studies, the researchers redefined the domains to comprehensively cover the smart city service domains. These services were then classified into six categories: Resources, Transportation and Mobility, Building and Infrastructure, Living, Governance, Economy, and Education. Detailed explanations of the reference studies and our definition of sub-domains are provided in this section.

Giffinger *et al.* [3] presented a smart city ranking of 70 small-to-medium European cities as an alternative to the primary smart city discussion of large cities. According to the study, smart city services can be categorized into six main parts: Smart Economy, Smart People, Smart Government, Smart Environment, Smart Mobility, and Smart Living.

TABLE 2. The domain of Smart City services.

<table>
<tr><th>Giffinger *et al.* (2007)</th><th>Desouza and Flanery (2013)</th><th>Piro *et al.* (2014)</th><th>Neirotti *et al.* (2014)</th><th>Anthopoulos (2015)</th><th>U4SSC (2017)</th><th>ISO/FDIS 37122 (2019)</th><th>This study</th></tr>
<tr><td>Smart Environment</td><td>Resources</td><td>Environmental Energy and Water</td><td>Natural Resources and Energy</td><td>Resource</td><td>Environment Energy</td><td>Environment and Resources</td><td>Natural Resources and Energy</td></tr>
<tr><td>Smart Mobility</td><td>Activities</td><td>Transportation</td><td>Transport and Mobility</td><td>Transportation</td><td>-</td><td rowspan="2">Transportation and Telecommunica tion</td><td>Transportation and Mobility</td></tr>
<tr><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">Smarter Building and Urban Planning</td><td rowspan="2">Buildings</td><td rowspan="2">Urban Infrastructure</td><td rowspan="2">ICT Infrastructure</td><td rowspan="2">Building and Infrastructure</td></tr>
<tr><td>Urban Planning</td></tr>
<tr><td rowspan="2">Smart Living</td><td rowspan="2">Processes</td><td rowspan="2">Public Safety Social Healthcare Education</td><td rowspan="2">Living</td><td rowspan="2">Living</td><td>Education, Health, and Culture</td><td rowspan="2">Health, Culture, and Population</td><td rowspan="2">Living</td></tr>
<tr><td>Safety, Housing, and Social Inclusion</td></tr>
<tr><td>Smart Government</td><td>Institutions</td><td>Government and Public Administration</td><td>Government</td><td>Government</td><td>-</td><td>Governance</td><td>Governance</td></tr>
<tr><td>Smart Economy</td><td>-</td><td>-</td><td>Economy and People</td><td>Economy</td><td rowspan="2">Productivity</td><td rowspan="2">Economy and Education</td><td rowspan="2">Economy and Education</td></tr>
<tr><td>Smart People</td><td>People</td><td>-</td><td>-</td><td>Coherency</td></tr>
</table>

To establish a conceptual framework for designing, planning, and operating a resilient city, Desouza and Flanery [46] divided smart city components into physical and social spheres. The physical sphere was subdivided into resources and processes, while the social sphere was subdivided into people, activities, and institutions. Piro *et al.* [99] classified the smart city services of the European Union based on ICT use into 41 sub-domains from 9 domains. Neirotti *et al.* [100] performed a literature review to create a framework for the smart city concept and evaluated the smart city policies from 70 cities worldwide to identify trends. They first classified urban policy domains as "hard" or "soft" and then divided them into six categories: natural resources and energy, transport and mobility, buildings, living, government, economy and people. These categories included 28 smart city services. Anthopoulos [101] examined the literature that classifies smart cities and categorized the services into seven domains. These discussions show that studies of existing concepts and elements of smart cities have focused on ongoing changes, from the application of new technologies from the Fourth Industrial Revolution to the existing components of urban space. In short, emerging smart cities are not creating new urban spaces or structures but are instead helping to improve current urban spaces and systems.

The classification framework used in this study was based on the service domain created by Neirotti *et al.* [100]. The most important feature of this original domain is that it is based on two axes: "application of technology" and "policy intervention." Application of technology, which is based on "hard" domains, refers to services that use ICT to physically enhance the urban environment. Policy intervention, which is based on "soft" domains, refers to services that use non-physical programs (i.e., education and tax cuts) to improve urban function and quality of life. This approach of classifying smart city services shows the relationship between each smart city policy and its corresponding element technology.

In this study, the researchers set a new classification based on the domain created by Neirotti *et al.* [100]. The modification has two purposes: the first is a change in the technology and concept of the smart city; and the second is a focused view of the service domain. Smart city is still an emerging concept with rapidly changing technology. Further, as the classification domain is developed for broader components of smart cities, some components do not clearly fit in the existing domains. By modifying the domains, collecting and comparing services should become easier. The biggest changes to the domains were in the "Building and Infrastructure," "Governance," "Economy," "People," and "Culture" domains. Because the spatial components of smart cities do not only exist in buildings, the "Buildings" domain may narrow the smart city concept. Since IoT and big data technology are

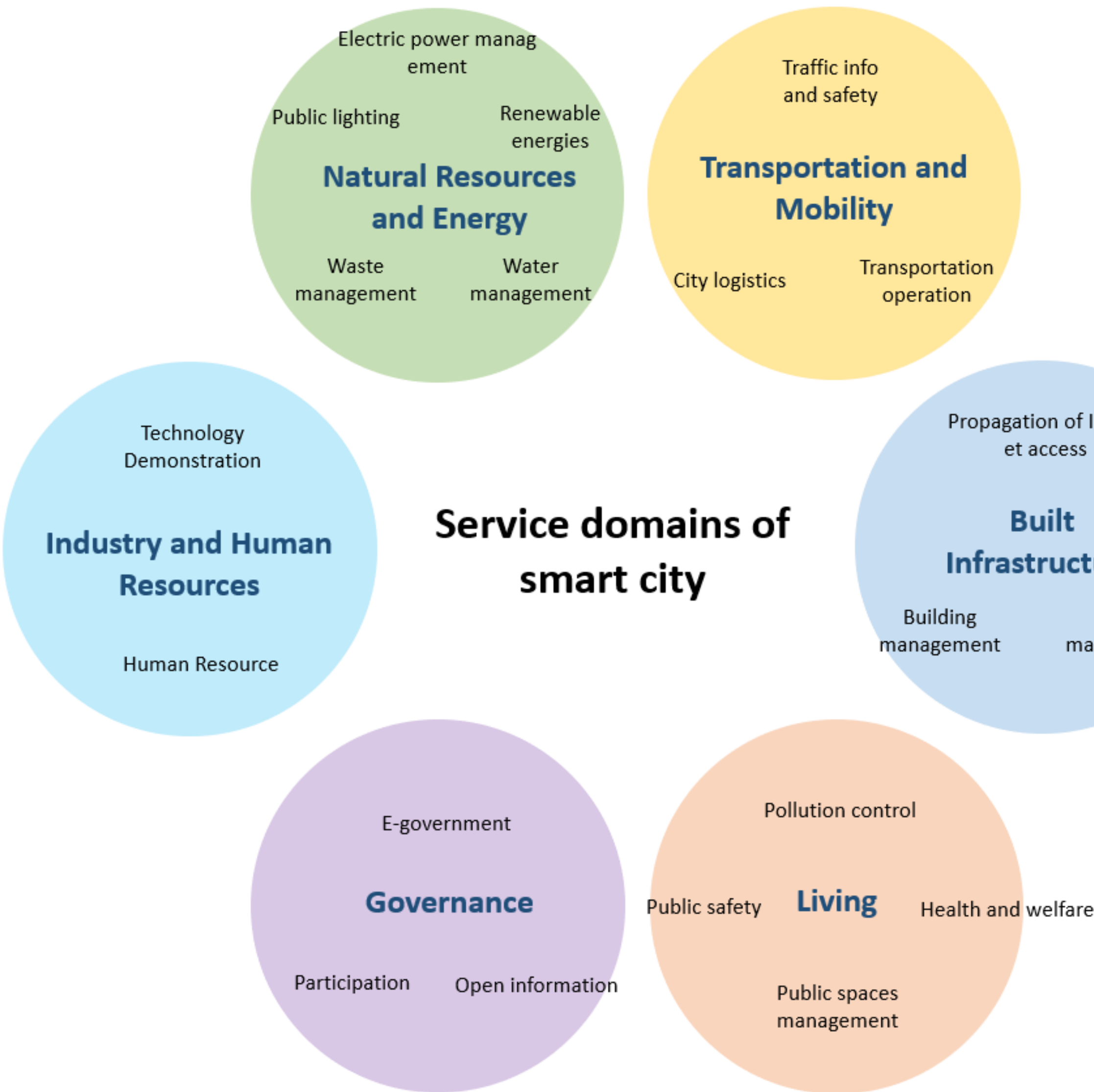

FIGURE 1. The six service domains of a smart city.

applied to various urban spaces, such as public spaces, plazas, bridges, tunnels, and parks, it is desirable to add more types of infrastructure to buildings. In the case of the government, the notion of governance could be more appropriate in terms of the participation of various interest groups for future city management (e.g., e-governance and citizen participation). The services of this domain involve operational policies for smart cities rather than the application of physical technologies. Therefore, the concept of the "Living Lab" was added to this category, and an education system for applying new technology was considered.

Other changes involved the exclusion or integration of some sub-domains and the segmentation of sub-domains that were too broad. Some sub-domains were modified to identify services more precisely. For example, the "Food and Agriculture" sub-domain was excluded since it mainly falls under "urban farming," and recent literature as well as case cities of this study hardly regard it as a smart city service. The name of the domain "Info-Mobility" was modified to express the broader purpose of promoting smart city mobility, including safety, efficiency, and accessibility of urban transportation. "People's Mobility" was changed to "Transportation Operations" to indicate management of pedestrian transit, private rapid transit, bicycling, and even public transportation systems. "E-democracy" and "Transparency" were also modified to cement their meanings in accordance with recent trends. Furthermore, because of recent trends in the 5G and fast Internet services segment, the significance of Internet access and data hub systems has been gaining greater value; therefore, the smart home was separated from facility management. Moreover, some urban services were merged with "Building services and Housing quality management" to create an integrated category called "Building management." Healthcare, Welfare, and Social Inclusion were also merged

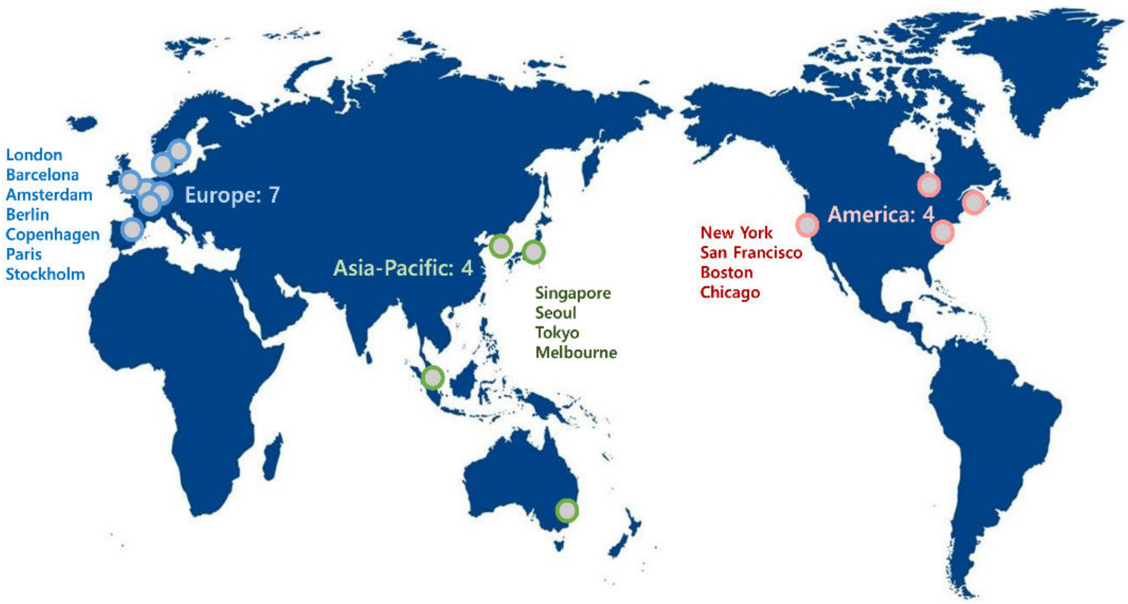

FIGURE 2. The research target cities (15 sample cities).

into a single category, "Health and Welfare." E-governance, Procurement, Culture, Cultural Heritage Management, Digital Education, and Human Capital Management were also modified for the same reason.

Therefore, this study utilized six domains: Natural Resources and Energy, Transportation and Mobility, Building and Infrastructure, Living, Governance, Economy, and Human Resources. These domains and their corresponding 18 sub-domains can be seen in Fig. 1.

III. RESEARCH METHODOLOGY

A. CASE SELECTION

This study first analyzed the trends in global smart city services. the researchers used the results to build a framework for comparing the services offered in the Korean NSSP to those offered in other regions. To collect data for the study, we first selected the cities and then examined documents published by municipal governments.

Case cities were selected according to criteria gleaned from responses to the following questions: First, which cities are "smart cities?" Second, does the city represent the region well? There have been many meaningful attempts to establish criteria that define smart cities. Discussions about smart cities have followed prior debates on similar concepts, such as sustainable cities, creative classes, and connected cities. After the discussion converged on the term "smart city," various researchers from research institutes and private firms made attempts to evaluate it [104], [109]; however, no consensus was reached on a definition [3], [102], [103]. Some researchers suggested that the availability of desirable features for residents of cities be considered a part of the criteria for a smart city. Affordable mobility, higher education, and safer streets are the main examples, and were derived from prior discussions. In contrast, other researchers suggested that technological measures for making cities better should be the criteria for being considered a smart city. For example, the 5G penetration rate and the share of renewable energy are measures of city achievements.

To represent all smart cities, a case city should share characteristics of other cities in the region. Smart city policy is dependent on characteristics such as social needs and governmental organization; analyzed characteristics should include not only geographical features but also sociocultural characteristics. According to the literature, there are more cities with a high degree of smart city development in Europe than in other regions [3], [100], [101]. Since the purpose of this study is to focus on regional trends, the cases were selected to provide a balance between regions. Therefore, smart city evaluation studies were collected [104]–[109], and used in order to select the cities with high evaluation and frequent selection in rankings in the studies.

Through our analysis, 15 cities were selected from among three regions: Europe, Asia-Pacific, and North America. Cities in other regions (Africa, the Middle East, and South America) were also studied as smart cities, but the cases are limited, making generalization in these regions difficult. Fig. 2 shows the 15 sample cities: 7 European cities (London, Amsterdam, Barcelona, Paris, Berlin, Stockholm, and Vienna), 4 cities in the Asia-Pacific region (Singapore, Seoul, Tokyo, and Melbourne), and 4 cities in North America, specifically the U.S. (New York, San Francisco, Boston, and Chicago).

The NSSP was established in 2018 by the Korean Agency for Infrastructure Technology Advancement (KAIA) and was funded by the South Korean government. The original plan was set by governmental research institutions and multiple organizations. The project was established to

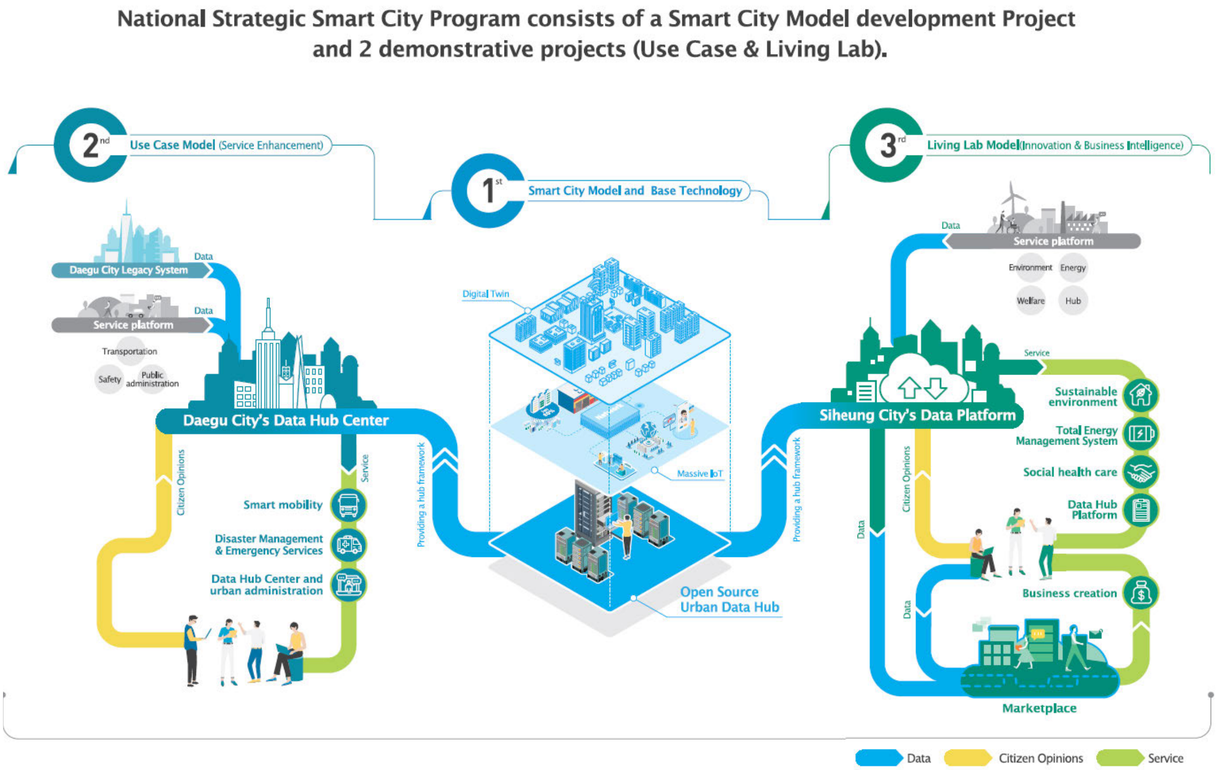

FIGURE 3. Project Structure of the National Strategic Smart City Program (Smart City Korea, 2019) [160].

build a smart city data platform, develop services to provide, and validate the smart city concept in a real-world application.

The NSSP consists of three core projects (Fig. 3). The first core project focuses on developing fundamental technology for smart cities. The main tasks of the first core project include developing data structures for core applications, building twin digital cities, and developing data processing and communication protocols. The second and third core projects are implementations of smart city concepts in the real world. The second core project focuses on implementation in large-scale metropolitan cities, with Daegu City selected as the site. The third core project focuses on mid-size cities, with Siheung City in Gyeonggi Province selected as the site. The technology is primarily targeted at the needs of the two selected cities; however, the project is intended to address the needs of Korean cities in general.

B. DATA COLLECTION AND ANALYSIS

Smart city development is a movement driven by multiple sectors of urban society. Public authorities, private corporations, and civil organizations are all drivers of smart city projects. Of course, the forms of smart city development differ according to the interests of the actors pursuing them. The NSSP was planned by public authorities and should be compared with other public smart city plans.

In this study, the researchers analyzed documents from municipal governments. The governments of smart cities publish documents detailing smart city policies to maintain the political support of the citizens and improve the city's brand. The documents from the sample cities are in various forms, such as reports, leaflets, and web documents. Documents collected and analyzed included: (1) smart city policy reports from governments, (2) general policies in accordance with smart city service frameworks, and (3) other publications from organizations affiliated with the municipal governments [110]–[148]. For the NSSP, official publications by KAIA were used. Publications from the pilot cities (Daegu and Siheung) were also used to supplement documents on services provided by municipalities [149]–[151].

The services provided under the NSSP were compared with other cities around the world using a cross-case analysis method. The smart city services for each city were listed according to the service framework, including 6 domains and 20 sub-domains, as described above in the background section. The global and regional trends of smart city services as seen in 15 cities were investigated and compared with the services of the NSSP. The similarities and differences in the services are interpreted for each domain. The factors affecting the spectrum of smart city services offered under the NSSP were examined, including both needs (demand side) and capacity (supply side).

IV. RESULTS AND DISCUSSION

A. GENERAL TRENDS

Table 3 shows service domains across cities on a global scale. The 6 domains and 20 sub-domains are in the two left columns, and names of the cities are at the top. The circle

TABLE 3. Smart city services by domain and cities.

Domain	City	London	Amsterdam	Barcelona	Paris	Vienna	Berlin	Stockholm	New York	San Francisco	Chicago	Boston	Singapore	Seoul	Tokyo	Melbourne	Main services by domain	Korean Smart City Strategic Project
	Region	Europe							America				Asia-Pacific				Global	South Korea
Natural Resources and Energy	Electric Power Management	●	●		●	●	●	●	●		●	●	●			●	Smart grid	Building Energy Managing System (BEMS)
	Public Lighting		●	●				●	●					●		●	Motion-sensing street lighting	
	Renewable Energies		●	●	●	●	●		●			●		●	●	●	Solar panel, Wind turbine	
	Waste Management	●	●		●	●	●	●	●				●		●	●	Smart waste bin, Recycling	
	Water Management	●		●			●		●				●		●		Water grid, Leakage sensing	
Transport and Mobility	City Logistics	●	●		●	●											Logistics optimization	
	Traffic Info and Safety	●	●	●	●			●		●	●	●	●	●	●	●	Transit Information, Parking sensing	Parking Dataframe Development
	Transportation Operation	●	●	●	●	●	●	●	●	●		●	●	●	●	●	Real-time tolling, Shared vehicle	Smart Mobility for Disabled People / Autonomous Vehicle Demonstration
Built Infrastructure	Facility Management	●	●	●			●		●		●			●	●		3D infrastructure modeling	5D Facility Auto-control / LiDAR Public Space & Facility Control
	Building Management		●		●	●	●	●	●				●	●	●	●	IoT infrastructure management	
	Propagation of Internet Access	●		●	●	●	●	●	●		●	●				●	Public Wifi	5G IoT propagation
Living	Pollution Control			●		●	●		●		●				●		Air quality monitoring	Fine Dust / Odor Detection / Traffic Noise Mapping
	Public Safety						●		●	●	●	●	●		●		Crime monitoring, Disaster prediction	Emergency & Crime Detection / Collapse & Flood Monitoring
	Health and Welfare	●	●	●		●	●	●					●	●	●		Emergency management, Remote healthcare, Living information	Wearable Senior Care / Smart Map & Navigation for Disabled People
	Public Spaces Management	●			●	●			●			●				●	Participatory public space management	
Governance	E-government					●	●	●		●	●		●	●			Electronic services	
	Participation	●	●	●	●	●	●	●	●		●	●		●		●	Citizen policymaking	Social Crowd Sourcing
	Open Information	●	●	●	●	●	●	●				●	●	●		●	Open data, Digital archiving	
Industry and Human Resources	Technology Demonstration	●		●	●						●		●	●			Citizen living lab	Living Lab Platform
	Human Resource	●		●		●		●			●			●			Data science education Enterprise support	Open Business Model

* A circle mark in a cell (●) represents that the city in the same column has service(s) in the corresponding domain.

mark (●) shows whether the city has a service or not, and the services in the sub-domains are shown in the right-hand column. The farthest column to the right shows services in the Korean NSSP, which will be explained in the next section.

In the Natural Resources and Energy domain, European cities provide the most services on average. Adaptive energy consumption regulation systems, such as smart grids and motion-sensing street lighting, have been adopted in 13 cities, indicating that energy efficiency is a global issue. The high demand for energy efficiency, as well as environmental sustainability, has led European cities to provide the most services in this domain, especially increasing renewable energy capacity. In Barcelona, the smart city plan was established as a pilot model in designated districts including the use of zero-energy blocks. In addition, most cities in Europe have waste recycling programs. In Asian cities, the populations are very densely distributed, so land-focused energy policies (such as wind and solar power) are difficult to apply. Instead, wasted heat energy is recaptured in cities where its use is spatially dense, such as Seoul and Tokyo. American cities provide limited services in this domain, but New York City plays a leading role in adopting diverse services, such as smart waste bins and energy storage technology. From a technological aspect, services in this domain depend heavily on electronic sensors. Smart grids, including electric and water grids, require automatic metering and an IoT system. Smart urban furniture such as street lighting or waste bins also need sensors. Renewable energy has been developed and adopted for decades, but their economic efficiency is still questionable. However, the achievements of the smart grid environment have been noticeable, which has afforded economic benefits to the providers [152] and lowered energy costs for the end users [153].

In the Transportation and Mobility domain, most cities operate multiple services. The services most commonly provided are transportation information sharing services. Specifically, most cities are operating platforms that provide parking information to citizens. San Francisco, where the use of personal vehicles is relatively high, implemented a citywide project providing parking information, including the availability of nearby parking spaces. This project has reduced the time citizens spend searching for parking spaces and has also decreased downtown traffic. Road traffic information services have been provided for decades, but recently this information has been integrated into navigation systems, allowing drivers to select optimal routes and traffic volume to be dispersed. In Asian cities with high levels of public transit use, detailed transit information services are provided. In Seoul, the locations of transit vehicles and their estimated arrival times are provided via a smartphone application; most stops in the inner-city area have kiosks that display this information.

In contrast, only European cities operate services in logistics. In other regions, logistics is generally considered a private sector activity, but European municipal governments play more of a role in transporting smart freight. Since European countries are adjacent to each other, the European Union is also subsidizing the establishment of an integrated and smart logistics network. Shared transportation is another big issue in the field; most cities support shared vehicle and bicycle services. In addition, new technologies for smart parking and smart lighting systems for streets have recently been developed and adopted as a convenience measure [154], [155].

In the Building and Infrastructure domain, cities are digitizing their buildings and built infrastructures to achieve various goals. Built infrastructure is regarded as one of the measures used to achieve other goals. In addition, digitizing the built infrastructure is an important goal for providing a virtual platform for the spatial planning of city policies. In this domain, few differences are found. Differences in social and spatial characteristics do not affect policies in built infrastructure management.

Higher energy efficiency is one of the most important objectives; multiple cities have adopted energy-efficient services into their built infrastructures. In New York City, smart thermostats have been installed in some buildings to moderate air conditioning automatically, as well as to enhance energy efficiency. Some cities are auto-controlling buildings to enhance the safety and security of the infrastructure. Digital mapping of infrastructure is an emerging task for most cities. Urban planning simulation, 3D mapping, and IoT sensing of moving objects are common services in this domain. In London, underground utilities and infrastructure are modeled in digital 3D space, and in Berlin building information modeling (BIM) is used to optimize building performance and urban planning. Another important service is propagating universal Internet access for citizens. Installing more broadband and wireless network facilities is an important task for all cities.

In the Living domain, cities in different regions provide different services. In North America, possession of firearms is common, making crime prevention a key issue in the domain. In San Francisco and Chicago, crime data are mapped and provided via the Internet to inform citizens. In New York City, sound sensors are used to detect unexpected gunfire. In Europe and Asia, crime prevention services are not provided, except in Berlin. However, real-time healthcare services for seniors and citizens with disabilities are operated in cities in those regions. In Singapore, the government collects biometric data to detect emergencies for those with high risks, such as senior citizens and cardiac patients.

Air quality is a significant concern in five of the sample cities. In Berlin, traffic emissions are monitored to enhance air quality. In Tokyo, disaster prevention and mitigation are dominant focus areas in this domain, and sensor and communication technologies are used to mitigate damage from earthquakes, floods, wildfire, and infectious diseases. In short, services in the Living domain are selected based on the social needs of the city, and various technological measures are used in different cities to solve problems.

In the Governance domain, European cities have various civic participation platforms. Every European municipality in the study operates a smartphone application that allows electronic participation by citizens. In Stockholm, citizens' direct suggestions are collected for improvements in municipal administration. In Vienna, a crowdsourcing service is applied for better governance. Further, all of the European cities provide city data openly to citizens. The European Union also promotes open data through integrated data platforms for European cities.

In the Asia-Pacific region, the focus of each city is very different. Seoul provides participation services similar to those in Europe, such as reporting problems or suggesting policy proposals; even citizens voting for individual policies is used as reference data in decision-making. Singapore has an advanced city data platform and e-government. While Tokyo provides highly technology-focused smart city services overall, no service in this domain is provided. Melbourne is similar to the U.S. and provides limited public services in this domain.

In the Industry and Human Resources domain, few cities provide significant services. However, many cities are linking smart city services to the regional economy, and new initiatives in this domain continue to increase. Technology demonstrations, such as living labs, fab-labs, and testbeds, have emerged as potential technology solutions. Furthermore, specific municipal authorities and corporations have focused on the usage of smart technology for improving cultural life; that is, citizens are provided with enhanced smart services that can improve the quality of their life experiences [156] or efficiently personalize the services provided to them [157].

In summary, global smart cities provide many services in common, such as smart grids, traffic sensing, and open urban data. In particular, services in the Transportation and Mobility domain, as well as the Governance domain, are widely adopted in the sample cities. Furthermore, rising technologies such as autonomous vehicles, IoT networks, and renewable energy sources, are in initial phase trials. Regional differences are clear in that European cities stress sustainability, Asian cities operate more services related to transportation, especially mass transit, and American cities consider crime an important problem.

However, in most cities, the services are not based in a physical space, so that the spatial arrangement of smart city services is less considered. Additionally, technology for smart cities is not integrated into a complex platform, where its components can be comprehensively considered.

B. CHARACTERISTICS OF THE NATIONAL SMART CITY STRATEGIC PROGRAM

In terms of smart city services, the National Strategic Smart City Program (NSSP) covers all six domains. Table 3 compares the services of the NSSP against other global cities. The detailed projects and services of the NSSP are listed in Fig. 4. The entire project consists of three core projects. The first core project developed source technologies including data architecture and networking protocol and therefore does not include any particular services. The second and third core projects are based on living lab case cities. The second core project, which involves Daegu metropolitan city, mobile carrier SKT, and public developer LH, focuses more on mobility and infrastructure management. The third core project involves the relatively small city of Siheung, mobile carrier KT, and electricity producer KEPCO. Here, micro-scale management of energy, air quality and living environments are bigger concerns. The brief contents of the core projects and their corresponding service domains are displayed in Fig. 4, and the location and size of the case cities are also shown.

In the Natural Resources domain, an energy management system (xEMS) is being developed. xEMS is a form of a smart grid, which is a common service in smart global cities. As decentralized data-exchange technology such as blockchain advances, smart grid platforms for peer-to-peer (P2P) energy trading also gain in popularity [59]. However, the concept of smart grids is still dependent on centralized energy production. Most platforms for P2P energy trading are based on those of countries such as the UK, Germany, and the US [60], [61], and energy-producing infrastructure is still uncommon for individual households. The difference between NSSPs xEMS and conventional smart grids is their diversity in the spatial dimensions of the energy system. To save computing resources and enhance the accuracy of the system, a varying spatial scale of energy system management is efficient. The varying target energy systems include houses, commercial and business buildings, as well as factory complexes. Individual systems are integrated into the entire city scale, and power usage is automatically metered through an advanced metering infrastructure to manage the power demand and supply of the city. The key element of energy trading is its trading protocols and decision-making algorithms, and various attempts to build these using game theory or blockchain technology have been made [62], [63]. The NSSP is trying to utilize xEMS in a living lab case city (Siheung) as an experimental arena for technological advancement. xEMS is applied to houses and buildings in Siheung City, and the spatial distribution of energy demand is considered. Furthermore, it is envisaged that the concept of P2P energy trading will start with electric cars, Segways, or urban furniture. Korean Energy Storage System (ESS) providers such as LG Chem and SK Innovation will play an important role in building systems for P2P energy trading [149], [151].

In the Transportation and Mobility domain, the main trend in the development of services is the shift from mass transit to smart mobility. Transit is an important mode in Korean cities, and most existing global smart cities also provide transit services. However, the NSSP does not include services directly related to mass transit. One reason is that transit information is already collected and well provided, and it is one less feature in the project that needs to be newly developed. Another reason is the project's strong focus on demonstrating the use of autonomous vehicles. The NSSP

1st Core Project (Smart City Core Technologies)

Projects	Sub-projects	Domain
(1-1) Data Architecture	Open Data Hub Architecture Model	Not a Service
	Data Hub Core	
(1-2) Networking System	Large-scale Realtime IOT System	
	Environmental Massive IOT Network	
	Digital Twin Technology	
	Semantic Data Management	
(1-3) System Management	System cf System Management Tool	
	Smart City Index and Evaluation Tool	
	Smart City Co-working Program	

3rd Core Project (Siheung City)

Projects	Sub-projects	Domain
(3-1) Smart Environment	Crowdsourcing-based Fine Dust Simulation	Living
(3-2) Smart Energy	Home/Building/Infrastructure Energy Management (xEMS)	Natural Resources
(3-3) Smart Living	Video Bigdata-based Single Elder Care System	Living
	VR-based Mobility Support for People with Disabilities	Transportation
(3-4) Open Data Hub Center	Living Lab-based Data Hub	Infrastructure
	Smart City Business Model Development	Industry
	City Lab Service Verification	Not a Service
(3-5) User Business Model	Municipality-suggested Business Model Development	Mixed

2nd Core Project (Daegu City)

Projects	Sub-projects	Domain
(2-1) Smart Transportation	Smart Mobility Adoption	Transportation
	Shared Parking Data Structure Development	Transportation
(2-2) Smart Safety	Landslide/Flood Prediction	Living
	Emergency/Crime Rescue System	Living
(2-3) Smart Administration	5D-based Urban Infrastructure Management	Infrastructure
	Social Crowdsourcing	Government
(2-4) Open Data Hub Center	Use-case-based Data Hub	Infrastructure
	Smart City Business Model Development	Industry
	Use-case Service Verification	Not a Service
(2-5) Data-based Service Use Case	Municipality-suggested Use Case Development	Mixed

FIGURE 4. **Project contents of Korean National smart city strategic project.**

aims to test these vehicles in a designated district in the pilot cities. Siheung City provides a regulatory sandbox for smart mobility technologies, including autonomous vehicles, which give citizens cutting-edge mobility. In addition, the urban area of Siheung City is sparsely dispersed into small towns, and personal mobility is favored for moving from one town to another. Daegu City is also developing a prediction system for spatial transportation demand to provide demand-sensitive mobility as a service. Another core service in the domain is the development of a parking data structure. In old and dense cities, parking is a constant issue. Since providing parking information is a common service in global smart cities, the project also attempts to handle the problem. The project aims to not only develop a parking management system, but also standardize the smart parking data structure to create another smart city business.

The main task in the Building and Infrastructure domain, is modeling city space and infrastructure in real-time. This technological vision tries to apply real-time sensor data, as well as the newest socioeconomic data to manage buildings and facilities. The project involves various incident sensors (fire, flood, building vibration, crime, etc.), and the main goal is to support decision-making by providing choices. Of course, this requires economic analysis, and can be applied to other tasks. This service is a common concept in existing smart cities, and the NSSP is simply developing an advanced vision of existing global cities' 3D infrastructure simulation and visualization. In addition, propagation of the 5G network is similar to existing cities' (including Korean U-cities) broadband or Wi-Fi propagation.

In the Living domain, numerous services to allow for quick action on social issues are planned. Korea is one of the regions with the highest amount of fine dust in the world. Consequently, air quality issues have emerged in recent years throughout South Korea. Since air quality monitoring is adopted in many cities globally, the NSSP also adopted the service in pilot cities. In addition, the project extends pollution mapping to traffic noise and automatically detects individual pollution sources. Crime against women is another social issue in Korea; emergency and crime data are monitored and mapped, and an emergency rescue system is being developed. Spatial data of the incidents are also analyzed to detect patterns in the cities. The aging of society is another constant issue, leading to the development of wearable care devices for the elderly. This type of service is currently being used in Singapore and Amsterdam, and the NSSP has tried to enhance the detection of emergencies with the latest AI and 5G communication technologies.

In the Governance domain, a social crowdsourcing platform is being developed using a two-track approach. In the first core project, the smart city operation model is being developed. This model includes impact-projection and evaluation standards. In other core projects, crowdsourcing technology is being developed and applied. This technology aims to increase citizen participation in policy-making and

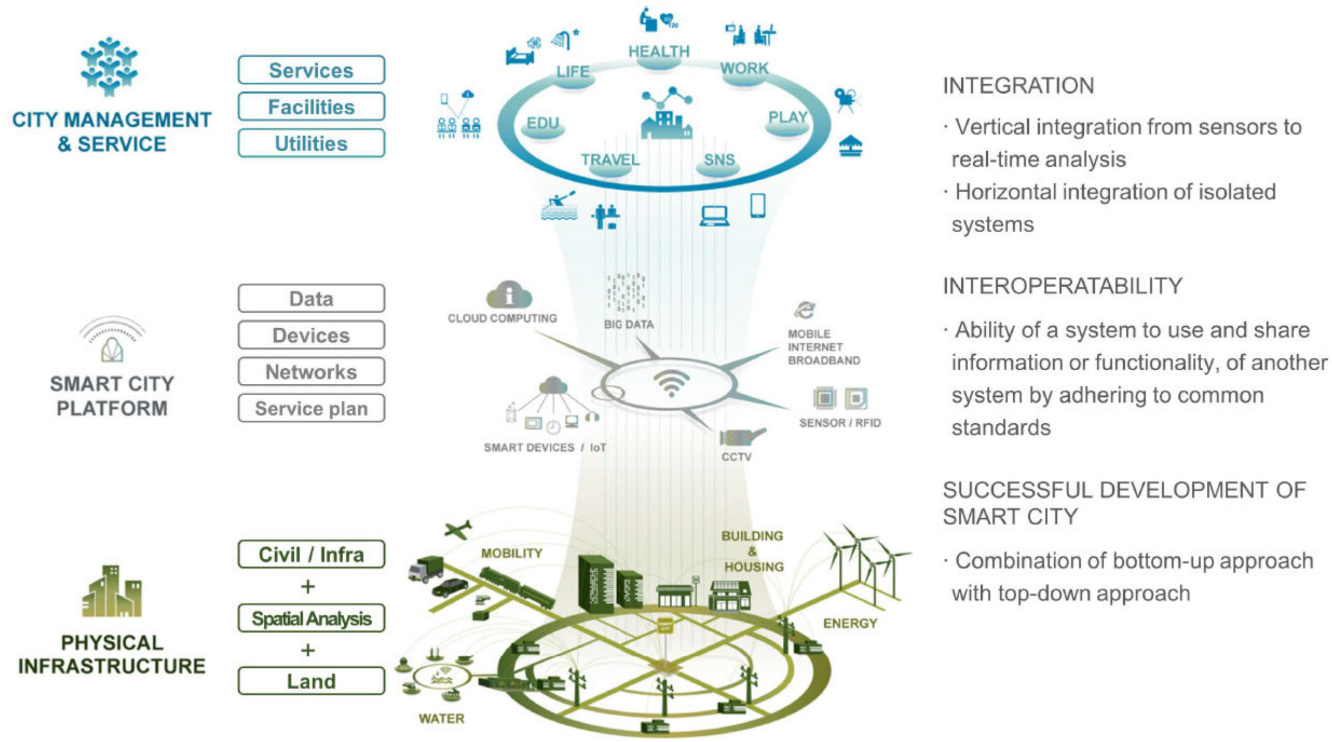

FIGURE 5. The layer-structure of smart city infrastructure, data, and service. (D. Cho, 2016) [161].

technological applications. This technological model is also applied to air quality monitoring. In European smart cities, citizen participation is common in smart city operations. In addition, cities like Barcelona and London actively utilize citizens' power to gather environmental information via sensors. In Korean cities, this kind of governance concept is not as familiar, therefore the NSSP is endeavoring to adopt a crowdsourcing governance concept.

In the Industry and Human Resources domain, the NSSP aims to create a sustainable business model for smart city industries. Nurturing smart city SMEs is one of the most important objectives of the project and every sub-project requires a model to ensure sustainability and to extend the business to other cities. Specifically, the project includes the development of a business model evaluation manual that can be used to support businesses associated with smart city projects. In the pilot cities, technologies being developed are presented via the living lab concept, which allows their readiness to be tested along with the impact of the service. In existing global smart cities, especially in Europe, the living lab concept has been commonly adopted. In contrast, no case has planned to directly support and manage the business models of service provider SMEs.

According to the analysis of global trends in section A, existing smart city services have strong policy-centered characteristics. Since municipal governments plan them, the services tend to generate immediate, noticeable effects. Therefore, existing smart city development has been very sensitive to trending issues and is driven by two strategies: subsidizing the adoption of new technology and providing diverse online applications that do not require high-end technology. Korean cities faced similar problems in previous smart city developments. In the case of Seoul, solar panel subsidies have been an important policy since 2012. Seoul is also operating an online application that provides a solar energy map of the city. This project has been in place for a significant period and has had a visible outcome; however, it was only slightly related to the development of new smart city technology. These problems were mentioned in an analysis report by the Korean government in 2018 [9].

The characteristics of the Korean NSSP can be summarized as follows: (1) high dependency on ICT, (2) development of futuristic technologies, (3) technology demonstrations in case cities. Primarily, in this project, smart city services which are highly related to ICT have mainly been planned. In fact, most of the services are simply advanced forms of existing smart city services. Parking information, an electric energy management system, and incidence detection have already been adopted in global smart cities. However, services that do not need data analysis or real-time telecommunication have been excluded. Furthermore, data structure is integrated into a unified platform to manage each smart city as a whole, even if there is no suggestion of a blueprint of how to connect different services.

Second, some services of the project try to develop immature, futuristic technologies such as autonomous driving or digital twins. These technologies cannot be immediately applied to citizens' lives, but the target is to advance these technologies and create new industrial sectors. Korean smart cities can be new laboratories, as well as market leaders for experimenting with new technologies. Therefore, the project ultimately focuses on developing and designing applications for future technologies. In this new marketplace, SMEs developing new technologies are involved, and the government supports these SMEs, financially and institutionally.

The other characteristic of the NSSP's service is its spatial basis. Every planned service of the project in the case cities of Daegu and Siheung City is based on a living lab. Detailed parking information is based on site in Daegu where parking sensors are installed, and a fine dust monitoring and prediction system is based on an actual site in Siheung City. This spatial basis can allow for technology development to be more easily demonstrated, and can be easily utilized in the spatial planning of city services.

V. CONCLUSION

In the 21st century, cities will become increasingly complex, and there will be more diverse urban problems. The smart city concept is emerging as a powerful, realistic solution for future problems [158], [159]. In 2020, the unprecedented spread of the infectious deadly disease COVID-19 has been recognized as a pressing problem, which has urgently shifted the revolution of wireless telecommunication.

A smart city is often described as a multi-layer system, which includes smart infrastructure, data platforms, and real-world services. From smart homes to smart grids, diverse services constitute the overall smart city service, and actualize the entire smart city system (Fig. 5). This diversity makes smart cities difficult to understand comprehensively. Since services are a substantial result of a smart city, existing literature studies how smart city services are structured. Moreover, services covered by smart cities vary according to needs, environment, or availability. To compare global smart cities and the Korean NSSP, understanding the domains of smart city services is necessary.

Leading global cities provide various smart city services in six service domains. Common services are smart grids, renewable energy, parking control, 3D city models, and citizen participation platforms. However, service coverage differs by region; European cities invest more in energy, resources, and democracy, while Asian cities focus on public transportation and disaster mitigation, and American cities provide more crime prevention.

The Korean NSSP's service includes new smart city services. Project services are focused on applying the newest telecommunication technology and analyzing data such as electric power demand or fine dust detection. At the same time, the project targets the development of future technology such as autonomous driving, which is not yet commonly used. This style of development is unprecedented in any other government, and can present an opportunity to solve smart city practice problems.

The first problem of existing smart city developments is poor integration among domains. The service domains coexist under the title of smart city but they themselves have little interaction or interrelationships. However, the NSSP has defined smart city services as being more focused on ICT. The NSSP's service development strategy has focused on developing services in areas in which Korea has an advantage. The Korean government and firms have significant experience in developing new urban spaces and building new transportation, infrastructure, and living services. The NSSP is developing various services in the Transportation, Living, and Built infrastructure domains, and this can be interpreted as a reinforcement of Korean strengths in the associated core technologies. However, the project has focused less on developing existing smart city services in the Natural Resources and Energy and Governance domains. In Korea, renewable energy is being promoted through other regional policies. Further, the concept of democratic governance is being applied through the living lab method of technology development in the third core project. In other words, the Korean definition of key smart city elements is based on the application of ICT, and other smart city services have been divided into other specialized domains. Although the academic discussion of smart cities has already shifted to a more ICT-centered concept [15], [38]–[40], an actual case or model has not yet been concretely planned.

Another problem of smart cities is their unsustainable and closed nature. Existing top-down-oriented smart city development depends heavily on governmental plans, and this has led smart city service providers to react passively to the plan. The NSSP sees smart cities as an industry that can strategically foster companies financially, especially SMEs. The main goal of the NSSP includes fostering smart cities as a new industry including developing business models for sub-projects. Existing smart cities have also been led by companies such as IBM and Siemens, but the practical effect has been limited because building a complete smart city that addresses public interest through public data requires the cooperation of government. The NSSP is a research and development project conducted by a consortium that includes telecommunications companies and strategically provides public support, such as the designation of a regulatory sandbox. Finally, the project was used as an experiment at two actual sites. The NSSP has achieved multiple goals targeting the development of technology that is more complete than the service itself. In contrast, since the technology cannot be provided without first being tested, the project was implemented in two pilot cities, which allowed local governments and companies to benefit from the experiment.

In summary, the Korean smart city research project, NSSP, provides three insights. First, the project shows recent shifts in techno-centric discussions of smart city literature. The ICT-centered discussion on smart cities was originally integrated with other discussions on sustainable cities or creative classes. However, recent literature has separated these concepts and the project involves only the technology aspects of the smart city concept. Second, the project shows a new strategy on policy, which supports smart cities to create more economic and industrial opportunity. Via this project, the Korean government is targeting incubation enterprises with related technologies. Consortiums of large mobile carriers and these SMEs are planned. Lastly, the project suggests some futuristic form of applications of smart city technologies.

Korean smart city development has led global smart city discussions since the advent of the U-city concept, but has also been criticized for its techno-centric characteristics. In the early 2010s, global smart cities were ''standardized'' to provide a common set of services, such as smart grids and electronic participation, neutralizing the techno-centricity problem to a certain degree. However, the Korean government considers techno-centricity its strength in focusing on developing technology as its main strategy. The difference between U-city and current smart city development is that while the U-city concept depends on building new cities, smart cities do not need new, large-scale construction. Instead, ICT is the core technology. Therefore, the Korean government can create economic opportunities in the smart city industry for Korean firms, including SMEs. The government's role in the Korean NSSP as an active organizer of smart city development has been noted. This integrity can also lead to the creation of substantial evidence for smart cities. At the same time, because smart city development and energy issues have been separated [7], [8], integrating sustainability into smart city development will become an important task.

In the global concept of smart city development, the South Korean case has been an important example for years [17], [28], and Asian smart city development has been characterized as including a larger role of governmental control [18]–[26]. The Korean NSSP is a new model for a governmental research project for smart city development. Through smart city development, the Korean government is attempting to invest in various technologies for the Fourth Industrial Revolution. At the same time, the government has to change the demand side; a new society is needed for further smart city development. Pilot cities are leading citizens to a future society by providing a living lab concept and crowdsourcing technology. In 2020, the global spread of COVID-19 has discouraged new development, but demand for a governmental role in the national economy is higher than ever. In the future development of smart cities, the Korean model, instead of a reliance on Asian models, can be generally adopted.

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