Smart City Industries

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Smart city industries can be defined as construction businesses based on IT manufacturing (precision instruments, electrical and electronic equipment), IT services (communications and broadcasting) and knowledge services (six fields such as finance and insurance, real estate and lease, professional, scientific and technical services).

Keywords: smart city ; smart city industry ; industrial ecosystem

1. Introduction

The technological innovation of the steam and internal combustion engines from the first and second industrial revolutions significantly influenced mass production, urbanization and economic agglomeration, and the third industrial revolution applied information and communication technologies (ICTs) to manufacturing, while also leading to the emergence of virtual space [1][2][3].

The current fourth industrial revolution with artificial intelligence (AI) and the Internet of Things (IoT) is leading the global economy and accelerating the convergence of business, industries and IT to create new business models, including a hyper-connected society [4]. In particular, smart cities are leading industrial innovation in the fourth industrial era, instigating a knowledge industries' boom.

Korea has developed ICT-driven smart cities to reinforce the national competitiveness and enhance industry value chains and production path chains through industrial ecosystems [5]. The development of smart cities has received public attention as a global city model to foster new value creation, technological innovation and sustainable development. Smart cities perform an increasingly important role in physical infrastructure management such as transport, security and safety, power supply, sewage treatment and water supply and management in cities [6][7][8]. Smart cities provide a new industrial paradigm based on the convergence of the built environment and ICTs [9].

Recently, smart cities have significantly affected changes in the industrial ecosystem with new forms of living and working environments such as smart homes, smart offices, smart mobility and living lab facilities in convergence with disruptive technologies and knowledge-based industries [10][11][12]. Furthermore, a smart city strategy focuses on urban sustainability in response to the recent fourth industrial revolution, climate change and economic recession [13][14][15]. Countries that did not respond to the needs of the industrial revolution will meet challenges to sustainable development [16].

Recently, researchers have tried to understand the industrial ecosystem within smart cities such as smart city industry ecosystems [5] and smart city governance/service/data ecosystems [17][18][19]. These studies investigated how to measure economic efficiency rather than empirical research focusing on the mechanism of the smart city industry. Despite many studies on smart cities, there is a lack of research on the evolving industrial ecosystem within smart cities.

2. Sustainable Smart Cities and Industrial Ecosystem: Structural and Relational Changes of the Smart City Industries in Korea

2.1. Concept of Smart City

A smart city is a concept of the city of the future that applies ICTs to urban services, infrastructure and governance, providing a range of ubiquitous, affordable and smart services to enhance citizens' quality of life [14][20][21][22]. The smart city was first introduced as a concept of ubiquitous computing, which aims to create a built environment in which computers are embedded in physical objects so that users cannot recognize the computers, known as the Internet of Things, and yet at the same time can use the objects [23]. Smart city researchers have tried to translate the ubiquitous computing environment to the city level [8]. Spin-off research on the ubiquitous city has been conducted in Korea with studies on cutting-edge technologies or successful technology implications for smart cities and communities. Most researchers agreed that smart cities should aim to improve the quality of life by using ICTs and provide integrated urban services across various fields such as local economy, health, security, education, culture and society [24][25][26][27].

Albino et al. [28] summarized the smart city into four dimensions: a city's networked infrastructure that enables social and cultural development; an emphasis on business-led urban development and creative activities for the promotion of urban growth; social inclusion of various urban residents and social capital in urban development; and preservation of the natural environment as a strategic component for the future. Neirotti et al. [24] classified the smart city concept into hardware and software domains. Smart cities focused on hardware use sensors and wireless technology to collect, store and analyze big data. In contrast, smart cities focused on software include education, culture, innovation and administration as well as communication with citizen participation. This study defines a smart city as one in which ICTs and eco-technologies (EcoTs) such as sensors, devices, artifacts and algorithms are linked, integrated and embedded with the traditional, physical city. ICTs and EcoTs are technologies such as sensors, devices, artifacts and algorithms, and a traditional city indicates the physical city. In other words, smart cities work only when there is a convergence of physically traditional cities with IT-related manufacturing business such as sensors, devices and artifacts, as well as knowledge services such as knowledge algorithms [5].

A smart city considers not only the technological aspect but also the sustainable development aspect. The United Nation's Sustainable Development Goals (SDGs) also point out the direction of achieving sustainability in every aspect of life [29]. Smart cities provide economic, cultural and social environments for residents to improve their quality of life. The primary aim of the sustainable smart city is to provide a mechanism for fulfilling the requirements of the present as well as the future generation inhabitants [30]. Nevertheless, it is debatable whether a simple implementation of the smart city could lead to a sustainable city for an improved quality of life [31][32]. Some researchers point out the negative aspects of smart cities as follows: territorial colonization in the digital age [33], the widening of inequality in technology (digital divide) [34], smart city plans that focus on corporate interests rather than citizens [35] and the negative impact within cities of new technologies, networks and infrastructure [36].

2.2. Smart City Industries

Previous literature was reviewed to define smart industries. There are no clear definitions and classifications for smart industries, and they are diversely classified depending on the research objectives and subjective views of researchers. Early studies on smart city industries include Cho et al. [37], Kim et al. [38] and Jeong [39].

Cho et al. [37] classified smart industries into 15 industries, including personal life (5), equipment (7) and public administration and services (3), to analyze how the ripple effects of adopting smart cities impact the Korean economy. Kim et al. [38] analyzed the ripple effects of Hwaseong and Dongtan smart cities in Korea on the regional economy through regional input–output tables. Smart city industries were sorted into 13 main categories of the input–output table, classified and defined as personal life (social and other services and 3 others), industry and economy (electrical and electronic equipment and 6 others) and public administration (electricity, gas and water supply and 1 other).

Jeong [39] focused on services in Asan cities in Korea to analyze the economic ripple effect of smart city development and identified four smart industries: electrical and electronic equipment; construction; communications and broadcasting; and others. Early studies on smart city industries defined them based on cities with smart services and defined construction and communication as key smart city industries.

As the smart city concept was further developed, studies defined smart city industries focusing on a new framework. Since 2010, smart city industries in Korea have been defined by focusing on operation and management as well as supply and demand, reflecting the views of experts.

Lim et al. [40] examined Seoul and divided smart industries into smart city infrastructure and utilization sectors to set the policy direction for smart cities. Industries were classified into eight main categories such as electrical and electronic equipment, construction, real estate and business services. Based on an expert survey to examine the characteristics of smart city industries, Lim et al. selected six industries such as construction and transport as smart city industries. Kim et al. [41] used a Delphi survey of experts to analyze how IoT sensors are related to smart city industries, deriving 30 subcategories of smart city industries.

Recent studies include Jo and Lee [5]. Unlike other studies, Jo and Lee focused on interpreting the relationship between smart city industries and other industries. IT manufacturing is hardware such as electrical and electronic equipment (sensors), and knowledge services are software such as specialized algorithms. IT services are defined as the communications and broadcasting industry, provided for people with the convergence and integration of IT manufacturing with knowledge services and construction.

Overall, studies on classifying smart industries have been conducted by consulting with smart city experts, meaning smart industries were classified differently depending on the smart city concept defined at the time of the research. Based on the main categories, smart industries were classified into IT manufacturing such as computers, electronic and optical devices and electrical equipment, IT services such as communications and broadcasting services, and knowledge services such as finance and insurance, professional, scientific and technical services, education, health and welfare and culture and sports.

By the industry analysis of smart cars, buildings and factories, it is possible to determine the detailed structure of the industries that form smart-X. Based on the subcategories of the input–output tables, smart-X industries had 20 common industries classified into IT manufacturing, IT services and knowledge services (**Table 1**).

Table 1. Components of the smart-X industry.

Industries of Input–Output Table	Smart Car	Smart Building	Classification
Semiconductor Manufacturing	●	●	IT Manufacturing
Electronic Display Manufacturing	●	●	
Printed Circuit Board Manufacturing	●	●	
Other Electronic Components Manufacturing	●	●	
Computers and Peripherals Manufacturing	●	●	
Communications and Broadcasting Equipment Manufacturing	●	●	
Medical and Measuring Devices Manufacturing		●	
Generator and Motor Manufacturing	●	●	
Electrical Conversion and Supply Control Unit Manufacturing	●	●	
Battery Manufacturing	●	●	
Wire and Cable Manufacturing	●		
Other Precision Instruments Manufacturing	●		
Wired, Wireless and Satellite Communications Services	●	●	IT Services
Other Telecommunications Services	●	●	
Information Service	●	●	
Software Development Supply Services	●	●	
Other IT Services	●	●	
Research & Development	●	●	Knowledge Services
Building and Civil Engineering Services	●		
Scientific and Technical Services	●	●	
Other Professional Service	●	●	

We analyzed the innovation ecosystem of smart city industries in Korea using input–output models and structural path analysis on data from 1960, 1975, 1995 and 2015 input–output tables and applying Korea's GDP deflator. The industries were classified into nine industries through minimum units of input–output tables by year: Agriculture and Mining, Traditional Manufacturing, IT Manufacturing, Energy, Construction, IT Services, Knowledge Services, Traditional Services and Other unclassified.

The spectrum of primary and secondary industries such as Agriculture and Mining and Traditional Manufacturing decreased over time, whereas those of smart city industries such as IT Manufacturing, IT Services and Knowledge Services are relatively increasing. This indicates that the external industrial structure is changing toward smart city industries. The smart city ecosystem analyzed with a focus on production showed an explosive quantity growth in IT Manufacturing, which showed approximately 10 times higher growth than the industry showing the lowest growth, and 2.5 times higher growth than the industry showing the second-highest growth. Typical examples of IT Manufacturing as a smart city element are semiconductors, computers, internet network and sensors. The rapid growth of IT Manufacturing as a smart element industry has great implications for the entire economic structure, indicating that the value-added is greater than other industries.

Growth rates for industries in which goods and services are input in terms of technical coefficients were relatively higher in smart city industries such as IT Manufacturing, IT Services and Knowledge Services than others. This indicates that the demand for smart city industries is rapidly increasing, which means that other industries took informatization and smartification with a focus on IT Manufacturing, IT Services and Knowledge Services industries and that smart city industries are replacing others. By the analysis of production inducement coefficients, manufacturing industries such as IT Manufacturing were found to have a greater ripple effect than service industries such as IT Services and Knowledge Services. The average increase rate of production inducement coefficients was highest in IT Services and Knowledge Services, which indicates that the potential for the ripple effect in these two industries was growing, and they create greater value-added than other industries.

The number of paths in structural path analysis indicates the complexity and connectivity of the entire ecosystem. The path analysis found the structure of the smart city industry ecosystem had complexity and connectivity and was evolving. Unlike analysis of production, technical coefficients and production inducement coefficients, the structural paths from IT Manufacturing to other industries decreased due to the stronger direct paths of IT Manufacturing, indicating that direct transactions between IT Manufacturing and other industries are increasing. IT Services and Knowledge Services showed an increase in all structural paths, indicating that they are emerging as key industries that create value chains of new industries and are serving as accelerators for the development of other industries.

Smart city industries are at the center of industry convergence and reinforce transactions among other industries. The number of paths needing the intermediary role of smart city industries is increasing. Paths including two or more of the three smart industries are also increasing in a highly significant result. In particular, paths with IT Services and IT Manufacturing or paths with IT Services and Knowledge Services, which had not existed before 1995, first appeared in 2015, consistent with industry convergence. IT Services creates value chains of new industries. Overall, the ecosystem of smart city industries showed convergence and evolution, creating value chains of new industries. IT Manufacturing, IT Services and Knowledge Services are growing as important industries. The qualitative, quantitative and convergence path analysis results presented in this study show sustained growth in the smart city industry.

References

1. Lucas, R.E. Lectures on Economic Growth; Harvard University Press: Cambridge, MA, USA, 2002.
2. Mokyr, J. The second industrial revolution, 1870–1914. In Storia dell'Economia Mondiale; Citeseer: Princeton, NJ, USA, 1998; pp. 219–245. Available online: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.481.2996&rep=rep1&type=pdf (accessed on 19 August 2021).
3. Rifkin, J. The Third Industrial Revolution: How Lateral Power is Transforming Energy, the Economy, and the World; Macmillan: New York, NY, USA, 2011.
4. Park, S.J.; Kim, B.W. 4 th Industrial Revolution and Open Access Network for Smart City. In Proceedings of the 2018 Portland International Conference on Management of Engineering and Technology (PICMET), Honolulu, HI, USA, 19–23 August 2018; pp. 1–10.
5. Jo, S.S.; Lee, S.H. An Analysis on the Change of Convergence in Smart City from Industrial Perspectives. J. Korean Reg. Sci. Assoc. 2018, 34, 61–74.
6. Lee, S.H.; Yigitcanlar, T.; Han, J.H.; Leem, Y.T. Ubiquitous urban infrastructure: Infrastructure planning and development in Korea. Innovation 2008, 10, 282–292.
7. Yigitcanlar, T.; Han, H.; Kamruzzaman, M.; Ioppolo, G.; Sabatini-Marques, J. The making of smart cities: Are Songdo, Masdar, Amsterdam, San Francisco and Brisbane the best we could build? Land Use Policy 2019, 88, 104187.
8. Leem, Y.; Han, H.; Lee, S.H. Sejong Smart City: On the Road to Be a City of the Future. In International Conference on Computers in Urban Planning and Urban Management; Springer: Cham, Germany, 2019; pp. 17–33.
9. Lee, S.H.; Han, J.H.; Leem, Y.T.; Yigitcanlar, T. Towards ubiquitous city: Concept, planning, and experiences in the Republic of Korea. In Knowledge-Based Urban Development: Planning and Applications in the Information Era; Igi Global:

Hershey, PA, USA, 2008; pp. 148–170.

10. Lee, S.H.; Leem, Y. Identification of Knowledge Driven Production Path through ICTs Industry as a Tool of Knowledge Sharing and Knowledge Management in Knowledge City. J. Korean Urban Manag. Assoc. 2015, 28, 409–434.
11. Jo, S.S.; Baek, H.J.; Han, H.; Lee, S.H. An Analysis on the Expert Opinions of Future City Scenarios. J. Korean Reg. Sci. Assoc. 2019, 35, 59–76.
12. Hawken, S.; Hoon Han, J. Innovation districts and urban heterogeneity: 3D mapping of industry mix in downtown Sydney. J. Urban Des. 2017, 22, 568–590.
13. Cretu, L.G. Smart cities design using event-driven paradigm and semantic web. Inform. Econ. 2012, 16, 57.
14. Guan, L. Smart steps too a better city. Gov. News 2012, 32, 24–27.
15. Jo, S.S.; Lee, S.H.; Leem, Y. Temporal Changes in Air Quality According to Land-Use Using Real Time Big Data from Smart Sensors in Korea. Sensors 2020, 20, 6374.
16. Pomeranz, K. The Great Divergence; Princeton University Press: Princeton, NJ, USA, 2021.
17. Gupta, A.; Panagiotopoulos, P.; Bowen, F. An orchestration approach to smart city data ecosystems. Technol. Forecast. Soc. Chang. 2020, 153, 119929.
18. Rotună, C.; Gheorghiță, A.; Zamfiroiu, A.; Anagrama, D.S. Smart City Ecosystem Using Blockchain Technology. Inform. Econ. 2019, 23, 41–50.
19. Pellicano, M.; Calabrese, M.; Loia, F.; Maione, G. Value co-creation practices in smart city ecosystem. J. Serv. Sci. Manag. 2018, 12, 34–57.
20. Bakıcı, T.; Almirall, E.; Wareham, J. A smart city initiative: The case of Barcelona. J. Knowl. Econ. 2013, 4, 135–148.
21. Caragliu, A.; Del Bo, C.; Nijkamp, P. Smart cities in Europe. J. Urban Technol. 2011, 18, 65–82.
22. Chen, T.M. Smart grids, smart cities need better networks [Editor's Note]. IEEE Netw. 2010, 24, 2–3.
23. Weiser, M. Some computer science issues in ubiquitous computing. Commun. ACM 1993, 36, 75–84.
24. Eger, J.M. Smart growth, smart cities, and the crisis at the pump a worldwide phenomenon. I-WAYS-J. E-Gov. Policy Regul. 2009, 32, 47–53.
25. Chia, J.; Lee, J.B.; Han, H. How Does the Location of Transfer Affect Travellers and Their Choice of Travel Mode?—A Smart Spatial Analysis Approach. Sensors 2020, 20, 4418.
26. Han, H.; Lee, S.H.; Leem, Y. Modelling Interaction Decisions in Smart Cities: Why Do We Interact with Smart Media Displays? Energies 2019, 12, 2840.
27. Han, J.H.; Hawken, S.; Williams, A. Smart CCTV and the management of urban space. In Smart Technologies: Breakthroughs in Research and Practice; IGI Global: Hershey, PA, USA, 2018; pp. 508–526.
28. Albino, V.; Berardi, U.; Dangelico, R.M. Smart cities: Definitions, dimensions, performance, and initiatives. J. Urban Technol. 2015, 22, 3–21.
29. Pedersen, C.S. The UN sustainable development goals (SDGs) are a great gift to business! Procedia Cirp 2018, 69, 21–24.
30. Ahad, M.A.; Paiva, S.; Tripathi, G.; Feroz, N. Enabling technologies and sustainable smart cities. Sustain. Cities Soc. 2020, 61, 102301.
31. Höjer, M.; Wangel, J. Smart Sustainable Cities: Definition and Challenges. In ICT Innovations for Sustainability; Advances in Intelligent Systems and Computing; Hilty, L., Aebischer, B., Eds.; Springer: Cham, Germany, 2015; Volume 310.
32. Hollands, R.G. Will the real smart city please stand up? Intelligent, progressive or entrepreneurial? City 2008, 12, 303–320.
33. Datta, A.; Odendaal, N. Smart cities and the banality of power. Environ. Plan. D Soc. Space 2019, 37, 387–392.
34. Woyke, E. Smart cities could be lousy to live in if you have a disability. MIT Technol. Rev. 9 January 2019.
35. Greenfield, A. Against the Smart City: A Pamphlet. This is Part I of "The City is Here to Use"; Do Projects: New York, NY, USA, 2013.
36. Sennett, R. No one likes a city that's too smart. Guardian, 4 December 2012.
37. Jeong, S.Y. Economic Impact Analysis on the u-City Development. Master's Thesis, University of Seoul, Seoul, Korea, 2008.
38. Cho, B.S.; Jeong, W.S.; Kim, P.R. An Analysis on the Economic Effects for launching the ubiquitous City. In Proceedings of the Korea Technology Innovation Society Conference, Portland, OR, USA, 5–9 August 2006; pp. 273–286.

39. Kim, P.R.; Cho, B.S.; Jeong, W.S. The propagation effects on the regional economy induced by u-City construction in Wha-sung and Dong-tan city. J. Korean Inst. Commun. Inf. Sci. 2006, 31, 1087–1098.
40. Lim, S.Y.; Lim, Y.M.; Hwang, B.J.; Lee, J.Y. A study on the characteristics of the U-CITY industry using the IO tables. Spat. Inf. Res. 2013, 21, 37–44.
41. Sun, J.; Zhang, Y.; He, K. Providing context-awareness in the smart car environment. In Proceedings of the 2010 10th IEEE International Conference on Computer and Information Technology, Bradford, UK, 29 June–1 July 2010; pp. 13–19.