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Analyzing the Changes of Industrial Network from Smart City Perspectives*

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Abstract

The aim of this study is to analyze changes in industrial networks from a smart city perspective. Smart city industries are classified into ITM, ITS, and KS based on literature review and smart-x cases. These industries use technologies that enable rational industries to exhibit intelligence, thereby allowing the industries see, hear, smell, and feel. The changes in industrial networks are primarily centered on in–out degree centrality, closeness centrality, betweenness centrality, and industrial clusters. In this study, a social network analysis is conducted using input–output tables published by the Bank of Korea from 1960 to 2015, and the GDP deflator is applied for year-over-year analysis.

The key findings are as follows: First, the industrial network structure results in an increase in density. In the early stage, smart city industries are less influential owing to their smaller node size compared with those of classic industries, as well as their owing to their locations outside the range of networks. However, as time progresses, the number of nodes in smart industries increased in IT manufacturing and knowledge industries, and smart city industries are operated closer to network centers. Second, the centrality of smart city industries, in–out degree centrality, closeness centrality, and betweenness centrality result in network changes in IT manufacturing and knowledge industries, thereby rendering the independent development of smart city industries difficult. This implies that the structure of smart industries is affected by external industries. Third, although the number of industrial clusters has increased, the number of smart city industrial clusters have not. In addition, connections among smart city industries are insufficient. Changes have occurred in smart city industrial networks of IT manufacturing, IT service, and knowledge industries, albeit at an insignificant level. In conclusion, IT manufacturing and knowledge industries are the primary industries that will either promote or hinder the growth of the overall structure of smart city industries.

Keywords Smart City Industry, In-Out Degree Centrality, Closeness Centrality, Betweenness Centrality, Smart City Industrial Cluster
주제어 스마트시티 산업, 내·외향 연결 중심성, 인접 중심성, 사이 중심성, 스마트시티 산업 클러스터

Ⅰ. Introduction

The Fourth Industrial Revolution and smart cities have recently been at the center of attention all across the world. This is also the case for Korea. In early 2000, the country became the first in the world to create a brand named Ubiquitous City, also known as U-City, an urban space equipped with innovative information and communication technologies. The U-City was initially located centered around a new town area in an attempt to efficiently address urban issues and further improve the quality of life for urban residents. Subsequently, in 2008, the Act on the Construction,

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etc., of Ubiquitous Cities (also known as the U-City Act) was enacted, significantly promoting the establishment of U-Cities. The year 2017 was a turning point in the history of U-Cities, with two major milestones. First, the U-City Act was revised as the Act on the Promotion of Smart City Development and Industry (also known as the Smart City Act). Second, the name of U-City was changed to Smart City.

The major revisions made to the Act are as follows. First, the scope of the smart city (spatial range) was expanded. Second, initiatives to support the smart city industry were launched. Third, the criteria for the smart city and its performance management were modified. Among them, initiatives to support the smart city industry were intended to foster and promote smart cities as a new growth engine, opening the door to new industries and markets (Lee, J.Y. and Han, S.H., 2017). In the Smart City Act, the smart city industry was defined as the industry that creates added economic or societal value using smart city technology, infrastructure, and services while putting emphasis on technology convergence. The Act also specifies the scope of the smart city industry to be equivalent to or beyond that defined by not only domestic but also global smart city market research institutes, as well as other countries that pursue smart city initiatives (Lee, J.Y. and Han, S.H., 2017).

Here, the term "smart city" is not just a compound word of "smart (or ICT)" and "city" but a comprehensive concept that encompasses all efforts made to make cities smarter (Choi, B.M., 2005). In this respect, the concept of the smart city is considered to have transitioned from the concept of Virtual City defined by Martin Dodge in 1978 to the Information City defined by M. Hepworth in 1987, the Knowledge-based City by Richard V. Knight in 1989, the Intelligent City by Latterasse in 1992, the Network City by D. Batten in 1993, the Cyber Ville by Won Schuber in 1994, Ubiquitous Computing by Mark Weiser in 1996, and further to the 2003 concept of Ubiquitous City in Korea (Lee, S.H., 2020). When it comes to Korea, the year 1960, when the government started to embrace digitalization, is considered to be the beginning of what is now the smart city (Jo, S.S. et al., 2015).

The global smart city industry is expected to amount to 2 trillion dollars (about 2,300 trillion won) by 2027 (Frost and Sullivan, 2018). To be more specific, the communications network sector is expected to amount to 13.4 billion dollars (about 15 trillion won) by 2027, and by 2026, the solution service market and the social service market are expected to amount to 94.2 billion dollars (about 111 trillion won) and 225.5 billion dollars (about 261 trillion won), respectively (Navigant Research, 2018). The smart city industry is dedicated to creating an ecosystem for smart city industries, including smart economy, smart environment, and smart traffic solutions based on the convergence of a wide range of technologies in various applications, such as construction, energy, knowledge, and services (Lee et al., 2016; Jo, S.S. and Lee, S.H., 2018; and Jo et al., 2021).

Smart city initiatives are now blurring boundaries between industries while bringing innovation to today's industrial ecosystem through convergence. A case in point is the smart car. In the past, the automotive industry was classified under the category of the machinery industry but has now transitioned into a smart, complex industry, one that combines machinery, content, and IT solutions (Jo et al., 2021). Cars have now become a type of moving IT device. Furthermore, more than half of the components that comprise smart vehicles are expected to be digitalized by 2030 (Kim, B.J., 2014). Perhaps reflecting this reality, the recent lack of supply of semiconductors has disrupted automotive production across the world.

Furthermore, industries related to the smart city have gained significant attention across the globe and society, and extensive research on this issue has thus far been performed. On the domestic front, studies on the classification of U-City (smart city) industries (Kim, W.S., 2003; Kim, J.Y., 2003; Oh, J.Y., 2005; and Jeong, W.S. et al., 2006) and other studies on the effect of these smart city-related industries (Kim, B.H., 2005; Baik, K.H. and Suk, Y.K., 2006; and Kim, P.R. et al., 2006) have been conducted since the early 2000s. Since 2010, the relevant research has been focused on classifying smart city industries based on surveys of experts and further analyzing their ripple effects (Lim, S.Y. et al., 2011; Lim, S.Y. et al., 2013; and Kim et al., 2016). Recent research on the smart city industry is focused on analyzing its ecosystem while putting emphasis on convergence (Jo, S.S. and Lee, S.H., 2018; and Jo et al., 2021).

Unlike domestic studies focused on the evaluation of the effect of smart city industries, global research efforts have been directed toward the qualitative analysis of various relevant factors, such as the governance ecosystem (Hefnawy et al., 2015 and Pellicano et al., 2018), the smart city service ecosystem (Diaz-Diaz et al., 2017 and Rotuna et al., 2019), the smart city data management ecosystem (Mrazovic et al., 2016; Abella et al., 2017; Lnenicka et al., 2017; and Gupta et al., 2020). Overall, domestic studies have put too much emphasis on analyzing ripple effect using input-output models, while global research has failed to go beyond qualitative analysis. However, there is a growing need for analysis of industries to embrace more network-based analytical tools in order to more effectively analyze the integration of production systems coupled with complex economic structures (Cho, S.S. et al., 2011; Hidalgo et al., 2007; and McNerney et al., 2013). Extensive research is currently performed on the application of not only industry-related but also network-based analytical tools in industry and economy analyses. Cases in point include studies by Cho, S.S. and Kang, S.W. (2013); Cho, S.S. and Park. J.C. (2014); Park, M.S. et al. (2017); Lee, D.H. et al. (2018); Liu, Y. and Kim, D. (2019); and Liu (2019).

In this light, the purpose of the present study is to analyze changes in the network of the smart city industry using social network analysis (SNA). This study mainly deals with the following aspects. First, a literature review of research on the industrial and economic sectors using SNA is provided. Second, the items listed in the 1960, 1975, 1995, and 2015 input-output tables are classified under the categories of the smart city industry and the traditional industry. Furthermore, the observed changes are analyzed using the 2015 GDP Deflator. Third, the centrality involved in the smart city industry is examined in detail. Finally, a cluster analysis of the smart city industry is performed.

Ⅱ. Literature Review

Changes in economic and industrial structures have been mainly analyzed based on an input-output analysis-based method proposed by W. Leontief using input-output tables. In recent years, however, convergence between production systems of the economic and industrial sectors has been increasingly on the rise. In response, the analytical strategies for this purpose have gone beyond industry-related analysis to include network analysis, a more advanced and sophisticated analytical tool (Hidalgo et al., 2007; McNerney, J. et al., 2013; Cho, S.S. and Park, J.C., 2014). As such, extensive efforts to analyze economic and societal phenomena using social network analysis (SNA) have been made from various perspectives. In the present study, a literature review of previous studies that performed industry-related analysis and SNA was conducted. Kang, J.G. (2010) examined the service industry of OECD member states, especially with respect to its structure and ripple effect. To this end, an input-output model and network analysis were employed. The analysis was performed based on data obtained from the 2000 and 2005 input-output tables issued by the OECD. The major findings of the analysis are as follows. First, in terms of the industrial structure, the knowledge industry, including the service sector, accounted for a larger portion of the national production, added value, and employment in OECD member states than in other countries. However, the national production and added value achieved by the service industry in Korea were found to be relatively smaller compared to other OECD member states. Second, in terms of the ripple effect, the manufacturing industry was found to have a more significant effect on national production than the service industry in OECD member states. The service industry exhibited similar characteristics found in other industries that supply intermediate products. Korea's service industry was found to have a ripple effect similar to that of other OECD member states, but the ripple effect of the country's manufacturing industry was above average. Third, the productivity of Korea's service industry was less than half the average of other OECD member states. Labor productivity and related productivity were also found to be lower compared to other member states.

Shim, S.J. (2010) analyzed and compared the value chain network and industrial clusters of the automotive industries among Korea, China, and Japan. The international input-output tables for Korea, China, and Japan were used in the analysis. The value chain network of each country was compared in terms of network centrality, and the clusters were compared based on the network density. In-out degree centrality and network analyses were employed as analytical tools. The results are as follows. First, the out-degree centrality of the service industry was found to be high in all three countries, and it was also revealed that the service industry played an essential role in the automotive industry. Second, the steel industry was found to be closely related to the automotive industry, and it was also reported that steel was being replaced by alternative materials. Third, in Korea and China, machinery and mechanic-mechanic-based industries were more dominant than electrical and electronic industries, but in Japan, electrical and electronic industries were found to have a more dominant presence than other industrial sectors.

Cho, S.S. and Kang, S.W. (2013) studied the economic structure of Korea's entire industrial sector, along with their mutual impact on each other, based on network theory. The analysis was performed using data obtained from the 2000, 2005, and 2010 input-output tables, and a network economy model was employed as an analytical tool. The results showed that the gap in the degree of interconnectivity among industries was widening, but the level of interconnectivity among industries decreased was decreasing over time. In addition, the mutual impact that the country's core industrial sectors had on each other weakened over time, and at the same time, the degree of input-output interconnectivity tended to decrease.

Cho, S.S. and Park, J.C. (2014) analyzed changes in the effect of supply shocks on Korea's economic structure, especially in terms of sensitivity and persistence, for the period from 2000 to 2010. Here, the degree of sensitivity was analyzed based on closeness centrality, and the degree of persistence was examined using betweenness centrality. The analysis was performed using the data obtained from the 2000 and 2010 input-output tables issued by the Bank of Korea, and network analysis was employed as an analytical tool. The analysis results are as follows. The sensitivity of Korea's economic structure to supply shocks was found to increase. In contrast, the persistence of the impact of supply shocks decreased. The sensitivity to and persistence of shocks were found to be the greatest in power, gas, and water supply industries in 2000 but in the construction industry in 2010. These results indicated that the country's construction sector was quick to respond to and deal with external shocks to promote the construction business. This also demonstrated that the period of time taken for the ripple effect of shocks to spread across the construction sector shortened.

Lee, D.H. et al. (2018) analyzed the degree of interconnectivity between traditional manufacturing industries and knowledge-based service industries using network analysis. The degree of interconnectivity was quantitatively analyzed using an input-output model, and further network analysis was employed to visualize the results. Notably, closeness centrality and the minimum spanning tree (MST) were used as analytical tools to determine the effect of the degree of convergence between the manufacturing sector and the knowledge-based service sector on manufacturing productivity. The analysis was performed based on the data obtained from the 2005, 2010, and 2013 regional input-output tables. This study was focused on extracting an industrial backbone network from the given data and further analyzing changes in the degree of convergence and interconnectivity between different industries. The analysis results confirmed that the degree of interconnectivity between manufacturing and the knowledge service sector affected the production of the manufacturing sector. In addition, the knowledge service, at the heart of the convergence and interconnectivity between multiple industries, was found to continuously evolve in line with the advancement of manufacturing technology. Simply put, the productivity of manufacturing using intermediate or advanced technology was affected by the advancement of knowledge-based services. However, the integration and convergence with the knowledge service sector were found to negatively affect the production of manufacturing based on low- or intermediate-level technology. It was also worth noting that the effect of the integration and convergence with knowledge services varied from one region to another.

Liu, Y. and Kim, D. (2019) examined changes in the economic structure of China for the period from 2002 to 2015. The analysis was performed using data obtained from China's input-output tables, and the degree, closeness, and betweenness centrality indexes of the SNA were employed to analyze changes in the country's economic structure. Notably, the MST was used to analyze changes in its industrial clusters. The results showed that the integration between industries was centered around secondary industries, such as manufacturing and construction at the early stages, but over time, the tertiary industry became at the heart of such integration. Further, a sharp increase in the degree of interconnectivity with other industrial sectors was observed in the knowable-based service sector under the category of tertiary industries. The analysis of clusters revealed that industries isolated from others became increasingly fewer, and the degree of interconnectivity and closeness between industries was much higher in 2015 than in 2002.

In fact, the analytical focus of most previous studies was placed on manufacturing and (knowledge-based) service sectors while focusing on specific points of time rather than pursuing a comprehensive review of diachronic changes in the industrial structure. Many of them also failed to reflect global trends regarding the advance of ICT, along with the advent of the Fourth Industrial Revolution. Furthermore, little research has been performed on smart cities and the smart city industry, even though they have emerged as key issues of importance. Not only that, these studies had limitations in the conduct of convergence-based analysis to analyze the ripple effect of the service industry on others. Even some studies that attempted to conduct convergence-based analysis also failed to go beyond one-dimensional analysis in which only one or two centrality indexes were employed. In the present study, to overcome the limitations of the previous studies and analyze the convergence aspects of industrial sectors in more detail, a wide range of analytical approaches, including in-out degree centrality, betweenness centrality, closeness centrality, and network analysis, were used for analysis. By doing so, changes in the smart city industry of Korea were analyzed, especially with respect to its network structure, in a diachronic manner.

Ⅲ. Data and Model Used for Analysis

1. Analysis data

In the present study, the analysis was performed using the data obtained from the 1960, 1975, and 1995 input-output tables based on actual measurements issued by the Bank of Korea. The 2015 GDP Deflator provided by the Bank of Korea was applied to process these data in order to exclude the amount of nominal increase resulting from inflation. These input-output tables were then processed to reclassify the Small Sectors into 26 industry sectors while considering the existing Primary Sectors to more effectively analyze changes in the network of the smart city industry, as shown in Table 1. Among the reclassified 26 industry sectors, Item 165 (etc.) was removed. This category refers to those used in office work, spending activities by households or similar entities, and those recycled as their own industries. Office supplies, non-household spending activities, difficult-to-classify items, and scrap are included in this category. These other industries were considered not necessary for the analysis of the present study and thus were excluded from the scope of analysis.

Table 1. Reclassification of smart city industry

Small sector industry number in 2015	26 Industries		2 Industries
68-73, 75, 78-80	IT manufacture		Smart city industries
131, 132, 134-136	IT service		
133, 137, 138	Broadcast and publishing	Knowledge service	
139-142	Finance and insurance		
158, 159	Medical and human health service		
160, 161	Cultural service		
157	Education service		
146-150	Professional, scientific and technical activities		
1-8	Agriculture and fishing		Traditional industries
9-12	Mining and quarrying		
13-35	Light industry		
36-51	Chemical industry		
52-67	Non-metal and metal industry		
83-93	Manufacture of machinery		
94-100	Manufacture of transport equipment		
74, 76, 81, 82, 101-103	Others manufacture		
111-117	Construction		
104-110	Energy generation and supply		
129, 130	Accommodation and food service		
118	Wholesale and retail trade		
119-128	Transport service		
143-145	Real estate service		
155, 156	Public administration and defence service		
151-154	Business support services		
162-164	Other service		
165	Etc. (removal)		

In the present study, the smart city industry was classified with reference to many previous studies by Cho, B.S. et al. (2006); Kim, P.R. et al. (2006); Jeong, S. (2008); Lim, S.Y. et al.

(2011 and 2013); Kim et al. (2016); and Jo, S.S. and Lee, S.H. (2018). The smart city industry was extracted from the hallmarks of the smart city, including smart cars, smart buildings, and smart factories, according to the following procedure. First, key smart technologies were extracted from each case. Second, each technology was matched with the corresponding industry according to the classification criteria for information and communications technologies provided by the Telecommunications Technology Association (TTA). Third, all matched industries were then rematched according to the Korean Standard Industrial Classification provided by Statistics Korea. Based on the results reported in previous studies, along with the matching results between smart technologies and industries, the smart city industry was classified under the categories of IT Manufacture, IT Service, and Knowledge Service, as shown in Table 2.

Among the 25 industries, eight industries, including IT Manufacture, IT Service, Finance and Insurance, Broadcast and Publishing, Medical and Human Health Service, Cultural Service, Professional, Scientific, and Technical Activities, and Education Service, were classified under the category of the smart city industry. The following 17 industries were classified as traditional industries: Agriculture and Fishing, Mining and Quarrying, Light Industry, Non-metal and Metal Industry, Chemical Industry, Manufacture of Transport Equipment, Manufacture of Machinery, Others Manufacture, Construction, Energy Generation and Supply, Accommodation and Food Service, Wholesale and Retail Trade, Transport Service, Real Estate Service, Public Administration and Defense Service, Business Support Services, and Other Service.

The sub-industries of the smart city industry include those conducting activities related to the transmission and receipt of information and data, inputs, and outputs, and the collection, analysis, processing, and application of data. High value-added industries involved in the computation and control of service content and algorithms are also included in these categories. IT Manufacture are mainly focused on functions implemented by the movement of electrons, such as computation, measurement, and data storage, and wired and wireless communications equipment to transmit data and information, including voice data, are also included in this category (Bank of Korea, 2019). These industries are those serving to collect and transmit data as input and output in smart cities.

Table 2. Reclassification of industries using cases of Smart-X

Industries in input-output table	Smart car	Smart building	Smart factory	Reclassification
Semiconductor manufacturing	o	o	o	IT manufacturing
Electronic display manufacturing	o	o	o	
Printed circuit board manufacturing	o	o	o	
Other electronic components manufacturing	o	o	o	
Computers and peripherals manufacturing	o	o	o	
Communications and broadcasting equipment manufacturing	o	o	o	
Medical and measuring devices manufacturing	-	o	-	
Generator and motor manufacturing	o	o	o	
Electrical conversion and supply control unit manufacturing	o	o	o	
Battery manufacturing	o	-	-	
Wire and cable manufacturing	o	-	o	
Other precision instruments manufacturing	o	-	o	
Wired, wireless and satellite communications services	o	o	o	IT service
Other telecommunications services	o	o	o	
Information service	o	o	o	
Software development supply services	o	o	o	
Other IT services	o	o	o	
Research & development	o	o	o	Know-ledge service
Building and civil engineering services	o	-	-	
Scientific and technical services	o	o	o	
Other professional service	o	o	o	

IT Service under the S/W Sector was composed of five sub-industries. Most of these industries are based on S/W and services, including portal and online information mediation, internet news provision, database, online content, knowledge information, and online information processing

(Bank of Korea, 2019). These industries are considered to be representative of the smart city industry while serving various functions, including data analysis, processing, application, control, and monitoring. Knowledge Service was reclassified with reference to previous studies reported by OECD (1999), Hretcanu (2015), and J-Figueiredo et al. (2017). This category includes knowledge-based industries that control the entire content of the smart city, such as service, information, and knowledge-based artificial intelligence (AI) and decision-making algorithms (Lee et al., 2016). The smart city industry encompasses all technologies and industries that help equip traditional industries with intelligence to be able to see, hear, smell, and feel things as humans do (Lee et al., 2016 and Jo et al., 2021).

2. Analysis model

Changes in the network of the smart city industry were analyzed using various models, including in-out degree centrality, closeness centrality, betweenness centrality indexes of social network analysis (SNA), and the minimum spanning tree (MST). Centrality analysis is the process in which the relative importance or influence of each node of the smart city industry is measured. The MST is used to extract core backbone structures from a given network and display them as clusters.

The degree centrality represents the degree of centrality determined based on the number of surrounding nodes directly connected to a given smart city industry node. The higher the value of this degree centrality is, the more number of other industry nodes the corresponding industry node is connected to. In contrast, the smaller the value of this centrality is, the fewer number of other industry nodes the corresponding industry node is connected to. In this regard, the degree centrality is considered to be an index that represents the direct effect of a given industry on other industries (or any activity performed by a given industry on other industries) or the direct effect of other industries on a given industry (or any activity performed by other industries on a given industry) (Kim, Y.H. and Kim, Y.J., 2016).

The degree centrality of each industry (i) can be divided into in-degree centrality ($DC^{in}(i)$) and out-degree centrality ($DC^{out}(i)$). The in-degree centrality is a similar concept to what the forward linkage effect represents, while the out-degree centrality is similar to the backward linkage effect.

For example, if Industry A directly affects the productivity of Industry B, then the in-degree centrality of Industry A is 0, while the out-degree centrality of Industry A is 1. In contrast, if Industry A is directly affected by Industry B, then the in-degree centrality of Industry A is 1, while the out-degree centrality of Industry A is 0. An industry with high degree centrality is what enables other industries to create new opportunities. Further, this type of industry is directly connected to many other industries and thus can provide various alternative solutions to industrial growth (Liu, 2019). The two types of degree centrality, $DC^{in}(i)$ and $DC^{out}(i)$, can be expressed as Formula 1 and Formula 2, respectively, as shown below.

$$DC^{in}(i) = \frac{1}{n-1}\sum_{j=1}^{n} f_{ij} \quad (1)$$

Here, $DC^{in}(i)$ refers to the in-degree centrality of Industry Node i, and n refers to the total number of industries present in the network. f_{ij} represents the direct and indirect effect of Industry on Industry i when one unit of production is increased by Industry j.

$$DC^{out}(i) = \frac{1}{n-1}\sum_{j=1}^{n} f_{ji} \quad (2)$$

Here, $DC^{out}(i)$ refers to the out-degree centrality of Industry Node i, n is the total number of industries present in the network, and f_{ij} represents the direct and indirect effect of Industry i on Industry j when one unit of production is increased by Industry i.

The closeness centrality is measured using a method different from that used to estimate the degree centrality. To be more specific, the degree centrality is determined by counting the number of nodes, but in the determination of the closeness centrality, indirect connections involved in the network should also be considered. Thus, the distance between industries is a key concept to be considered. This centrality is used to calculate the distance between a given node and all other nodes present in the entire industrial network. A node whose total distance of paths to other industries is the shortest is the one with the highest degree of closeness centrality (Freeman et al., 1979). An industry with a high degree of closeness centrality is considered to have a large spillover effect on other industries. This is because the industry is capable of quickly spreading its production-related influence to other industries through the shortest path within the network.

This centrality is determined by calculating the average of the shortest distance (production inducement coefficient) of all industry nodes other than industry Node i and taking the reciprocal of the obtained value (because the centrality is inversely proportional to the distance). Accordingly, the closeness centrality can be expressed as Formula 3 as below.

$$CC(i) = (n-1) / \sum_{j=1}^{n} f_{ij} \tag{3}$$

Here, refers to the closeness centrality of Industry Node i, and n refers to the total number of industries present in the network. f_{ij} represents the production inducement coefficient (distance) that connects Industry Node i to Industry Node j.

The betweenness centrality represents how likely it is that a given industry is located between other industries within the network. Simply put, an industry that is located between other industries exhibits a high degree of betweenness centrality. Thus, the betweenness centrality can be interpreted as an index that represents how efficiently a given industry is able to serve as a medium (or mediation) between other industries (Borgatti et al., 2018). An industry with high betweenness centrality serves to control the entire production process and thus can be regarded as one of the key industries that drive a country's economy (Liu, Y. and Kim, D., 2019). The betweenness centrality can be expressed as Formula 4 below.

$$BC(i) = \sum_{i=1}^{n} \sum_{j=1}^{n} f_{iNj} / f_{ij} \tag{4}$$

Here, $BC(i)$ refers to the betweenness centrality of Industry i. n is the total number of industries present in the network, and f_{iNj} refers to the number of cases in which Industry Node N is located on the shortest path between Industry Node i and Industry Node j.

The cluster analysis was performed using MST. The method is able to extract the backbone of the industrial network from the product inducement coefficients that are positive or negative so that the core cluster structure can be determined (Quirin et al., 2008 and Lee, D.H. et al., 2018).

MST analysis is an algorithm that finds all shortest distances that can be extracted from the network and integrate them in a sequential manner. In the present study, the product inducement coefficient refers to the shortest distance that connects industries. Simply put, the smallest product inducement coefficient between Industry i and Industry j is first determined, and the two industries are then allowed to be connected through the determined shortest path. Industries that are already connected along the shortest distance are reexamined to determine whether the corresponding product inducement coefficient is the shortest. This procedure is repeated until all industries are involved in a single connection (Lee, D.H. et al., 2018). The MST combined with this algorithm is capable of extracting the core or backbone structures that ensure the greatest production inducement effect from the industrial network and further clustering them (Yu et al., 2015 and Liu, 2019). It can be expressed as Formula 5, below.

$$BN_{(KA)} = \min \sum_{p=1}^{n} net_{\,p(b_{ij})} \tag{5}$$

(However, $p(b_{ij})$ that has a cycle was excluded)

Here, $BN_{(KA)}$ is the backbone network implemented by the application of the MST, and $net_{p(b_{ij})}$ is the weight factor available on the network (net) path (p), i.e., the product inducement coefficient. The backbone network corresponds to the sum of the paths in which the product inducement coefficient becomes the smallest. In the present study, the product inducement coefficients multiplied by -1 were subjected to the MST analysis to determine the shortest path possible (Jo, 2021).

The industrial cluster structure can be extracted using the backbone network. Any industrial cluster extracted from the backbone network must be configured to allow at least three industry nodes to form a single cluster while including at least one path. Industrial clusters must satisfy the two requirements above to be valid. The boundary between clusters is where two links adjacent to a single node are connected in the opposite direction (Liu, 2019). Industrial clusters can be identified in the MST using this approach, and this relationship can be expressed as Formula 6.

$$Cluster_{(BN)} \Leftrightarrow N_{(i)} \geq 3 \wedge L_{(i)} \geq 2 \quad (6)$$

Here, refers to the MST cluster in the backbone network, and $N_{(i)} \geq 3$ means that the corresponding industry node has three or more values. $L_{(i)} \geq 2$ indicates that the corresponding industry link has two or more values (Jo, 2021). When these two conditions are true, industrial clusters extracted from the backbone network are considered to be valid.

Ⅳ. Analysis Results

1. Changes in industrial network structure

In the present study, social network analysis (SNA) was performed on the smart city industry, especially with respect to the in-out degree centrality, closeness centrality, and betweenness centrality. The network was represented using Gephi 0.9.2 and Multi Gravity Force Atlas 2 (MGFA2) algorithms. The MGFA2 algorithm is a force-directed network graph drawing method. Nodes tend to repel each other, and if multiple links are available for them, they start to attract each other. This relationship can be translated into an algorithm, and based on this algorithm, each node is moved until an equilibrium is achieved. The more links a given node is connected to, and the more links that are strong a given node includes, the more likely the node is to be located at the center. In contrast, the fewer links a given node is connected to, and the more links with a low weight factor a given node includes, the more likely the node is to be located out of the center.

The basic analysis results obtained using the SNA are presented in Table 3. The number of links included in the industrial network varied by year, i.e., the smallest at 445 in 1960 and the largest at 625 in 2015. The graph density was 0.742 in 1960 and increased to 1.042 in 2015. This indicates that as the number of links between industries increases, the network is increasingly diversified and complex, and the degree of integration and interconnectivity is on the rise.

The industrial network implemented based on the product inducement coefficients from the input-output tables is considered to be a complete network. If this is the case, however, it is difficult to identify the characteristics of the relationship between industries (Liu, Y. and Kim, D., 2019). In the present study, the annual average of product inducement coefficients was calculated and used as a threshold to determine the optimum number of links for the industrial network and identify the key characteristics of the relationship between industries.

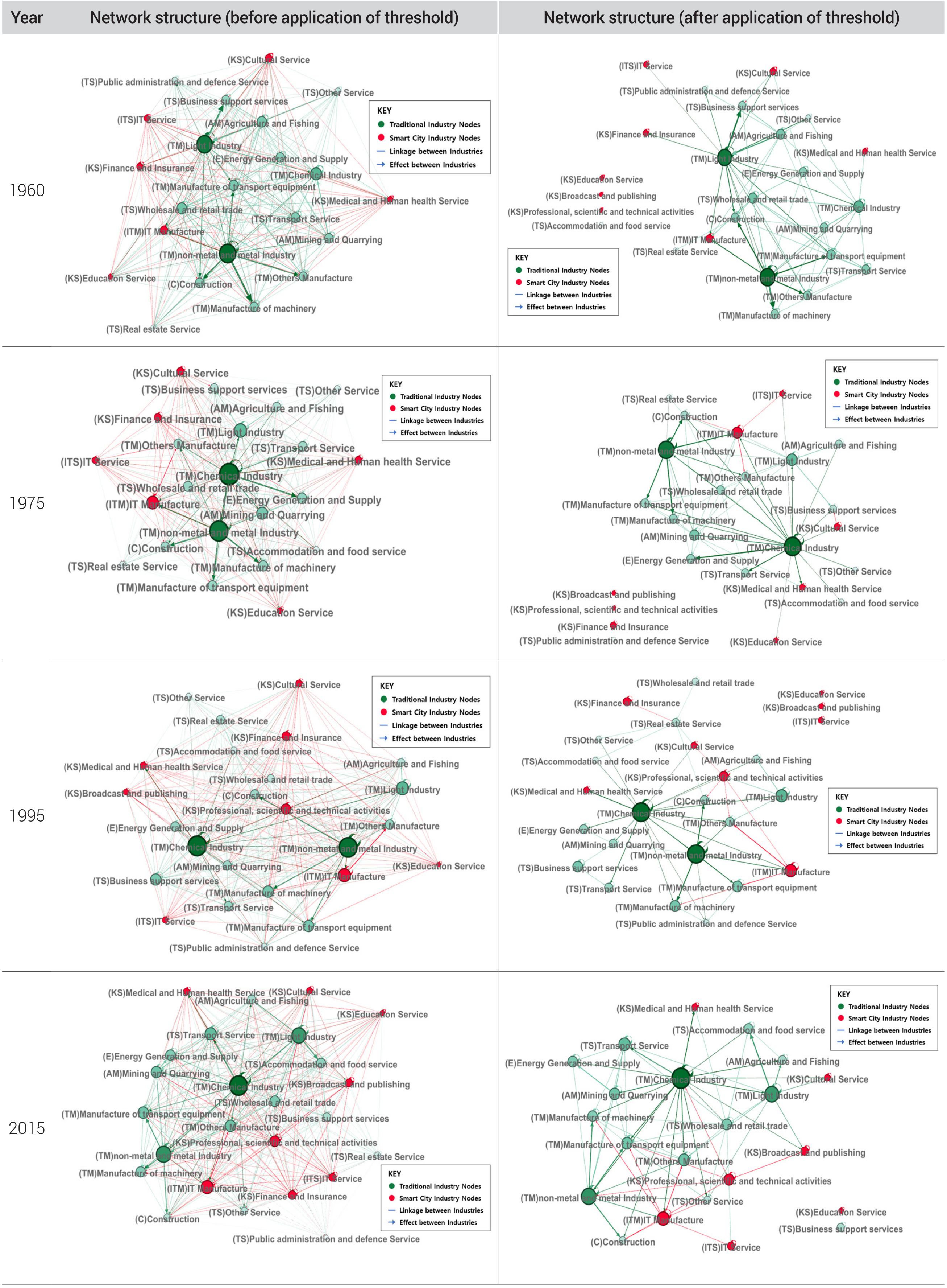
It was assumed that only when the direct and indirect effects of a particular industry on another industry when one unit of production was increased by the industry was equivalent to or larger than the average product inducement coefficient for the corresponding year, the two industries were considered to be correlated. The total number of links between industries in 2015 was found to be 625. Here, if the average product inducement coefficient, i.e., 0.092, is applied as a threshold, then the network is adjusted to be centered around 97 new links (15.52% of all links), as shown in Table 3 and Figure 1.

Changes in Korea's industrial network structure before and after applying the threshold for 1960, 1975, 1995, and 2015 are presented in Figure 1. Here, red nodes refer to those under the category of the smart city industry, while green nodes are those under the category of the traditional industry. The size and color of each node in the network were indicators of the degree centrality. A node whose size is larger and color is more intense has a higher degree central-

Table 3. Fundamental analysis of SNA

(Unit: number of)

Year	Node	Link of before threshold application (A)	Graph density (coefficient)	AVG of leontief multiplier (coefficient)	Link of after threshold application (B)	Rate of link (B/A, %)
1960	25	445	0.742	0.066	91	20.45
1975	25	466	0.777	0.080	86	18.45
1995	25	577	0.962	0.081	74	12.82
2015	25	625	1.042	0.092	97	15.52



Note: The red nodes are smart city industry. The green nodes are traditional industry.

Figure 1. Changes of network structure

ity. The network density continued to increase over time from 0.742 (1960) to 0.777 (1975) and 0.962 (1995), and further to 1.042 (2015). This indicated that the degree of interconnectivity between industries increased over time.

In the period from 1960 to 2015, most smart city industry nodes were located on the outskirts of the network, and their influence was relatively low. However, these smart city industry nodes increased in size over time. Among the smart city industries, IT Manufacture was found to be the most influential, considering its node size. In 2015, IT Manufacture and Knowledge Service (Broadcast and Publishing , as well as Professional, Scientific, and Technical Activities) started to shift toward the center of the network. This suggested that the smart city industry became increasingly influential.

Nodes that are not linked to any others are isolated nodes, and these nodes are considered to have an insignificant effect on other industries (Figure 1). In 1960, three industries under Knowledge Service (Education Service, Broadcast and Publishing, and Professional, Scientific, and Technical Activities) and one industry under Traditional Service (Accommodation and Food Service) were found to be isolated nodes. In 1975, three industries under Knowledge Service (Finance and Insurance, Broadcast and Publishing, and Professional, Scientific, and Technical Activities) and one industry under Traditional Service (Public Administration and Defense Service) were found to be isolated nodes. In 1995, two industries under Knowledge Service (Education Service and Broadcasting and Publishing and IT Service) were found to be isolated nodes. In 2015, Education Service under Knowledge Service and Business Support Services under Traditional Service were found to be isolated.

These isolated nodes were increasingly integrated into the network over time, and the number of isolated nodes decreased accordingly. Knowledge Service (education services) under the category of the smart city industry, in particular, was found to be not integrated into the network up until 2015. This suggested that content services or knowledge algorithms were not linked to other industries in smart cities. After applying the threshold value, changes were observed in the network structure. Smart city industries were now located around the edges of the network, away from its center. This indicated that the smart city industry was not highly influential on other industries, and its significance in the entire industrial network was not great.

2. Changes in centrality of smart city industry

1) Changes in in-out degree centrality

In the present study, the centrality of the smart city industry was analyzed based on the network structure, obtained after applying a threshold value. As a result, the in-out degree centrality was analyzed, as shown in Table 4. In the period from 1960 to 2015, the in-degree centrality was found to be very high in traditional industries. It was confirmed that Traditional Manufacture (NMMI, MTE, MM, etc.), Construction (C), and Traditional Service (BSS, TPS, AFS, etc.) topped the list of the in-degree centrality. IT Service and Knowledge Service, among the smart city industries, were shown in the list, but IT Manufacture was included on the list every year. Traditional industries also topped the list of the out-degree centrality as well, but more types of smart city industries (ITM, CS, PSTA, etc.) were found in the list of the out-degree centrality compared to the in-degree centrality.

Considering the annual averages of in-degree centrality, it was found that in 1960, industries with in-degree centrality above the annual average included Construction (C), Nonmetal and Metal Industry (NMMI), Manufacture of Machinery (MM), Manufacture of Transport Equipment (MTE), Chemical Industry (CI), and Others Manufacture (OM). Among the smart city industries, IT Manufacture was the ninth highest below average. In the period from 1975 to 2015, the in-degree centrality was still high in traditional industries. IT Manufacture among the smart city industries remained high on the list, above average, over the entire period.

Traditional manufacturing industries, including NMMI, MM, MTE, C, CI, LI, and OM, as well as IT Manufacture, made the top ten of the list. This result suggested that resources were directed toward industries where both goods and services were involved. The listed industries were considered to be directly or indirectly affected by other industries. This also indicated that in these industries, there was an increase in demand for intermediate goods from other industries. Since the 1970s, the Korean government has put in place various initiatives to promote the digitalization of

Table 4. Changes of in-out degree centrality (top 10)

Rank	In-degree								Out-degree							
	1960		1975		1995		2015		1960		1975		1995		2015	
	Ind.*	Val.**	Ind.	Val.	Ind.	Val.	Ind.	Val.	Ind.	Val.	Ind.	Val.	Ind.	Val.	Ind.	Val.
1	(C) C	2.1	(TM) NMMI	3.0	(TM) MTE	2.3	(TM) MTE	2.9	(TM) LI	3.7	(TM) CI	6.7	(TM) CI	5.0	(TM) CI	5.3
2	(TM) NMMI	2.1	**(ITM) ITM**	**2.9**	(TM) NMMI	2.3	(TM) MM	2.4	(TM) NMMI	3.6	(TM) NMMI	5.1	(TM) NMMI	4.2	(TM) NMMI	3.4
3	(TM) MM	2.1	(TM) MTE	2.6	(TM) OM	2.3	(TM) LI	2.4	(TS) WRT	2.4	(AM) MQ	3.1	**(ITM) ITM**	**2.2**	(TM) LI	2.8
4	(TM) MTE	2.0	(TM) OM	2.5	(TM) MM	2.2	(TM) NMMI	2.3	(AM) AF	2.2	(TM) LI	2.5	(TM) LI	2.0	**(ITM) ITM**	**2.4**
5	(TM) CI	2.0	(C) C	2.5	**(ITM) ITM**	**2.1**	**(ITM) ITM**	**2.2**	(AM) MQ	1.9	(TS) WRT	2.4	(TS) BSS	1.9	(TS) TPS	2.2
6	(TM) OM	2.0	(TM) MM	2.5	(TM) LI	2.0	(TM) CI	2.1	(TM) CI	1.7	**(ITM) ITM**	**2.1**	(TS) RES	1.6	(AM) MQ	2.0
7	(TM) LI	1.9	(TM) LI	2.4	(TM) CI	2.0	(TM) OM	2.1	(TS) TPS	1.6	(AM) AF	1.4	(AM) MQ	1.6	(TS) WRT	2.0
8	(TS) BSS	1.8	(TM) CI	2.3	(C) C	1.8	(TS) AFS	2.0	(TM) MTE	1.3	(TM) MM	1.4	(TM) MM	1.6	(TM) OM	1.7
9	**(ITM) ITM**	**1.6**	(E) E	2.2	(TS) BSS	1.6	(E) E	1.8	**(KS) SC**	**1.2**	**(KS) SC**	**1.3**	(TM) MTE	1.5	**(KS) PSTA**	**1.7**
10	(E) E	1.5	(TS) TPS	1.9	(TS) TPS	1.6	(C) C	1.8	(E) E	1.2	(TM) MTE	1.2	**(KS) PSTA**	**1.5**	(TM) MTE	1.6
AVG		1.9		2.5		2.0		2.2		2.1		2.7		2.3		2.5

Note: Agriculture and Fishing=AF, Accommodation and Food Service=AFS, Business Support Services=BSS, Chemical Industry=CI, Cultural Service=CS, Construction=C, Energy Generation and Supply=E, IT Manufacture=ITM, Light Industry=LI, Mining and Quarrying=MQ, Manufacture of Machinery=MM, Manufacture of Transport Equipment=MTE, Non-Metal and Metal Industry=NMMI, Others Manufacture=OM, Professional, Scientific and Technical Activities=PSTA, Real Estate Service=RES, Transport Service=TPS, Wholesale and Retail Trade=WRT
*Ind.: Industry
**Val.: Value

administrative processes. In line with these policies, the government and local governments have pushed forward various infrastructure projects to make more computers available and establish network infrastructure. To this end, large budgets were allocated, and this may lead to an increase in the in-degree centrality of IT Manufacture.

Similar to the in-degree centrality, the out-degree centrality was relatively high in traditional industries. Among them, MQ, in particular, remained high on the list. This was attributed to the direct or indirect effect of basic resources, such as coal, natural gas, and minerals, being transferred to other industries. Among the smart city industries, IT Manufacture, CS, and PSTA exhibited high out-degree centrality. This demonstrated that these industries were the core industrial sectors of the smart city industry. ITS was not found in the list, but IT Manufacture and Knowledge Service remained on the list from 1975 and 1960 onward, respectively. The out-degree centrality of IT Manufacture and Knowledge Service was found to increase in a steady manner. Considering the annual averages of the out-degree centrality, it was found that the out-degree centrality of all listed smart city industries was below average. This suggested that even though some smart city industries remained high on the list, their spillover effect on other industries was not as large as that of traditional industries.

Overall, it was concluded that the out-degree centrality of the smart city industries was higher than the in-degree centrality. In other words, the smart city industry is more likely to directly or indirectly affect other industries rather than being affected by them.

2) Changes in closeness centrality

Changes in the closeness centrality were analyzed, as summarized in Table 5. Similar to the in-out degree centrality, the closeness centrality was also found to be higher in traditional industries than in smart city industries. However, smart city industries largely remained higher on the list of closeness centrality compared to the list of the in-out degree centrality, demonstrating that the number of smart city industries with high closeness centrality increased. In the period from 1960 to 1975, two or more industries under the category of the smart city industry remained high on the list, and in the period from 1995 to 2015, three or more smart city industries were included on the list.

SC under Knowledge Service remained on the list in the period from 1960 to 1975, but was no longer included on the list from 1995 onward. IT Manufacture first appeared on the list in 1975 and remained on the list until 2015. Both PSTA and FI under Knowledge Service first appeared in 1995. Among them, FI remained on the list until 2015.

Considering the annual averages of the closeness centrality, it was found that the closeness centrality of the listed smart city industries was largely above average. However, FI (0.6) and PSTA (0.5) under Knowledge Service in 1995 and IT Manufacture (0.4) in 2015 exhibited values lower than the average. Among the smart city industries, IT Manufacture and Knowledge Service (FI, CS, and PSTA) showed a relatively high degree of closeness centrality, demonstrating that these industries are quick to affect other industries or detect spillover effects derived from other industries.

IT Service under the category of the smart city industry was not included on the list of closeness centrality. This suggests that the smart city industry of Korea has been mainly built on Knowledge Service and IT Manufacture. Overall, the closeness centrality analysis results showed that the smart city industry was quickly affected by other industries when they were subject to economic shocks. This means that the smart city industry can grow in line with the growth of other industries but is less likely to grow on its own.

Table 5. Changes of closeness centrality (top 10)

Rank	1960		1975		1995		2015	
	Ind.*	Val.**	Ind.	Val.	Ind.	Val.	Ind.	Val.
1	**(KS) CS**	**1.0**	(TM) MM	1.0	(TS) RES	1.0	**(KS) FI**	**1.0**
2	(TS) BSS	1.0	**(KS) CS**	**1.0**	(TM) MM	1.0	(TM) CI	1.0
3	(C) C	1.0	(C) C	1.0	(TM) MTE	1.0	(TS) TPS	0.6
4	(TM) LI	0.9	(TM) CI	1.0	(TM) CI	0.9	**(KS) PSTA**	**0.6**
5	(TS) WRT	0.7	**(ITM) ITM**	**0.8**	**(ITM) ITM**	**0.8**	(AM) MQ	0.5
6	(TM) NMMI	0.7	(AM) MQ	0.7	(TM) NMMI	0.6	(TS) WRT	0.5
7	(AM) AF	0.6	(TS) WRT	0.7	**(KS) FI**	**0.6**	(TM) OM	0.4
8	(AM) MQ	0.6	(TM) LI	0.6	(C) C	0.6	(TM) NMMI	0.4
9	(TS) TPS	0.6	(TM) NMMI	0.5	(AM) MQ	0.5	**(ITM) ITM**	**0.4**
10	(E) E	0.5	(AM) AF	0.4	**(KS) PSTA**	**0.5**	(TM) MTE	0.4
AVG		**0.8**		**0.8**		**0.8**		**0.6**

Note: Agriculture and Fishing=AF, Business Support Services=BSS, Cultural Service=CS, Chemical Industry=CI, Construction=C, Energy Generation and Supply=E, Finance and Insurance=FI, IT Manufacture=ITM, Light Industry=LI, Mining and Quarrying=MQ, Manufacture of Machinery=MM, Manufacture of Transport Equipment=MTE, Non-Metal and Metal Industry=NMMI, Others Manufacture=OM, Professional, Scientific and Technical Activities=PSTA, Real Estate Service=RES, Transport Service=TPS, Wholesale and Retail Trade=WRT
*Ind.: Industry
**Val. : Value

3) Changes in betweenness centrality

Changes in the betweenness centrality were analyzed, as shown in Table 6. Traditional Manufacture (CI and NMMI) and Traditional Service (TPS and RES) exhibited a high degree of betweenness centrality. NMMI, CI, and LI under the category of Traditional Manufacture remained on the list over the course of the entire period. In this respect, these industries are considered to serve as a key bridge among other industries, while driving the flow of production in the Korean economy. This result was consistent with the analysis results of in-out degree centrality and closeness centrality described above, which was attributed to the country's economic structure and system built on traditional manufacturing and service sectors.

The betweenness centrality of the listed smart city industries was largely found to be below average. In the period from 1960 to 1975, one industry (CS) or two industries (CS and IT Manufacture) under the category of the smart city industry remained on the list. IT Manufacture remained on the list from 1975 onward, and PSTA and FI under Knowledge Service first appeared on the list in 1995. These results can be interpreted to mean that the smart city industry is enhancing its role as a bridge that connects one industry to another. IT Manufacture, in particular, can be regarded as one of the core industrial sectors that drive the smart city

Table 6. Changes of betweenness centrality (top 10)

Rank	1960		1975		1995		2015	
	Ind.*	Val.**	Ind.	Val.	Ind.	Val.	Ind.	Val.
1	(TM) NMMI	23.0	(TM) CI	40.5	(TM) CI	33.0	(TS) TPS	77.0
2	(TS) TPS	19.0	(TM) NMMI	24.0	(TS) RES	21.0	(TM) MTE	71.2
3	(TM) CI	16.3	(TM) LI	22.0	(C) C	20.0	(TM) CI	46.4
4	(TM) LI	10.7	(AM) MQ	21.0	**(KS) PSTA**	**20.0**	(TM) OM	43.0
5	(E) E	10.3	**(ITM) ITM**	**4.0**	(AM) MQ	18.0	(TM) LI	42.8
6	(C) C	9.0	(C) C	3.5	(TM) LI	12.0	(TM) NMMI	26.8
7	**(KS) CS**	**6.0**			**(ITM) ITM**	**9.0**	**(ITM) ITM**	**11.2**
8	(TM) MTE	2.8	-		(TM) NMMI	8.0	(TS) WRT	10.6
9	(TS) BSS	0.8			(TM) MM	2.0	-	
10	-				(TM) MTE	2.0		
AVG		9.8		11.5		14.5		32.9

Note: Business Support Services=BSS, Chemical Industry=CI, Construction=C, Cultural Service=CS, Energy Generation and Supply=E, IT Manufacture=ITM, Light Industry=LI, Mining and Quarrying=MQ, Manufacture of Machinery=MM, Manufacture of Transport Equipment=MTE, Non-Metal and Metal Industry=NMMI, Others Manufacture=OM, Public, Professional, Scientific and Technical Activities=PSTA, Real Estate Service=RES, Transport Service=TPS, Wholesale and Retail Trade=WRT

*Ind.: Industry

**Val.: Value

industry. In other words, the smart city industry is now transitioning from a passive one that is easily affected by other industries to an active one that significantly affects other industries. These results were consistent with what was intended by the smart city-related policies implemented back then by the government, including initiatives for digitalization. These policies included the Ultra-high Speed ICT Infrastructure Project (1995), First General Plan for Informatization Promotion, Master Plan for Establishing Ultra-high Speed ICT Infrastructure (1996), e-Korea (2002), IT-839 (2004), u-Korea (2006), and First and Second Master Plans for U-City (2009 and 2014). These government policies contributed to the promotion of the smart city industry and its convergence with other industries (Jo et al., 2021).

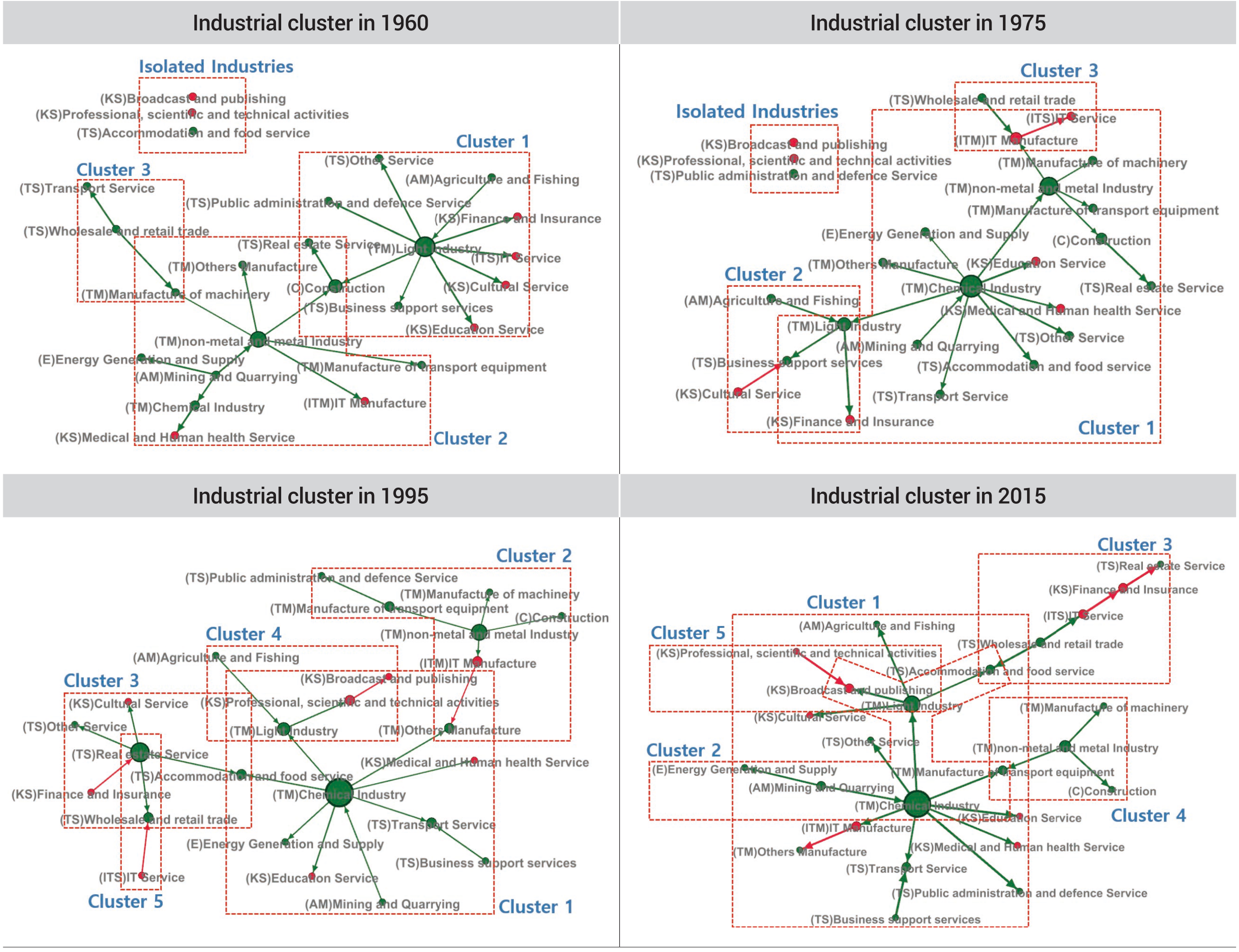
3. Changes in clusters of smart city industry

First, the backbone network of the smart city industry was established and, based on the results, clustering was performed to obtain clusters of the smart city industry. The analysis results are shown in Figure 2 and Table 7. The size of each node represents the level of degree centrality. Links (arrows) that connect two nodes indicate the direction in which the effect of the corresponding product inducement coefficient is exerted. Nodes that are not connected by links are isolated nodes. These industry nodes are those that do not transfer spillover effects to other industries.

In the 1960s, the growth of the Korean economy was mainly driven by traditional manufacturing industries, including light industries and non-metal and metal industries. The analysis results showed that in 1975, the country's economic growth was mainly spurred by the chemical Industry. In 1995, the chemical industry and light industry were the main growth engines, and in 2015 as well, the chemical industry and light industry were the country's key industrial sectors. These results were in line with the actual changes made in the industrial structure of Korea.

Broadcast and Publishing, and Professional, Scientific, and Technical Activities were found to be isolated nodes both in 1960 and 1975. Accommodation and Food Service was an isolated node in 1960, but it was later replaced by Public Administration and Defense Service in 1975. From 1995 onward, no isolation nodes were observed. This indicated that the interconnectivity of the smart city industry increased over time, mainly driven by Broadcast and Publishing, as well as Scientific, and Technical Activities.

Clustering was performed according to the number of nodes. The number of clusters varied from three to five. It was found that the number of clusters that were centered around smart city industries increased. The number of clusters was three in 1960, and the number increased to five in 2015. Isolated nodes were mostly industries related to Knowledge Service. Indeed, BP under the category of Knowledge Service remained isolated until 1985. Smart industry clusters that were centered around smart city industries did not exist. The main nodes of most clusters were mainly composed of traditional industries, e.g., Chemical Industry (CI). This was attributed to the large scale of these traditional industries, such as the chemical industry,



Note: The red nodes are smart city industry. The green nodes are traditional industry.

Figure 2. Changes of smart city industrial cluster

in terms of production volumes.

Smart city industries were found to be concentrated in Cluster 1, with the largest number of nodes. However, considering the way of spillover effects spreading within the MST and the size of nodes included in the cluster, these smart city industry nodes were too far from each other, even to be considered to be classified as a single cluster. This result suggested that the major role of the smart city industry was to serve traditional industries as a subsidiary industry. It was also found that in Korea, the influence of these smart city industries was too weak for clusters centered around them to be created.

In 1960, Finance and Insurance, Culture Service, and Education Service, under Knowledge Service, as well as IT Service, were strongly interconnected with Light Industry. IT Manufacture was linked to the Non-metal and Metal Industry, and Medical and Human Health Service was related to the Chemical Industry. In 1975, as the presence of Chemical Industry expanded, Education Service under Knowledge Service and Medical and Human Health Service, which were connected to Light Industry in 1960, ended up forming new links to Chemical Industry. IT Manufacture was linked to Non-metal and Metal Industry. Notably, it was also linked to IT Service.

In 1995, Finance and Insurance, Culture Service, and IT Service were linked to Real Estate Service. Broadcast and Publishing was linked to Professional, Scientific, and Technical Activities, while Professional, Scientific, and Technical Activities was linked to Light Industry. IT Manufacture was linked to the Non-metal and Metal Industry, and Medical and Human Health Service was linked to Chemical Industry. In 2015, Chemical Industry was linked to Education Service, Medical and Human Health Service, and IT Manufacture. Light Industry was found to be correlated with Broadcast

Table 7. Changes of smart city industrial cluster

(Unit: number of)

Industry cluster		1960	1975	1995	2015
Cluster 1	Main node	(TM)LI	(TM)CI	(TM)CI	(TM)CI
	Connected node	11	19	12	18
	Smart industry node	ITM(0), **ITS(1)**, **KS(3)**	**ITM(1)**, **ITS(1)**, **KS(3)**	ITM(0), ITS(0), **KS(4)**	**ITM(1)**, ITS(0), **KS(5)**
Cluster 2	Main node	(TM) NMMI	(TM)LI	(TM) NMMI	(TM)CI
	Connected node	11	5	7	7
	Smart industry node	ITM(1), ITS(0), **KS(1)**	ITM(0), ITS(0), **KS(2)**	**ITM(1)**, ITS(0), KS(0)	ITM(0), ITS(0), **KS(1)**
Cluster 3	Main node	(TS)WRT	(ITM) ITM	(TS)RES	(TS)WRT
	Connected node	3	3	6	5
	Smart industry node	ITM(0), ITS(0), KS(0)	**ITM(1)**, **ITS(1)**, KS(0)	ITM(0), ITS(0), **KS(2)**	ITM(0), **ITS(1)**, **KS(1)**
Cluster 4	Main node	-	-	(TM)LI	(TM) NMMI
	Connected node			4	4
	Smart industry node			ITM(0), ITS(0), **KS(2)**	ITM(0), ITS(0), KS(0)
Cluster 5	Main node	-	-	(TS)RES	(TM)LI
	Connected node			3	3
	Smart industry node			ITM(0), **ITS(1)**, KS(0)	ITM(0), ITS(0), **KS(2)**
Isolated nodes		(KS)BP, (KS) PSTA, (TS)AFS	(KS)BP, (KS) PSTA, (TS) PADS		

Note: Agriculture and Fishing=AF, Accommodation and Food Service=AFS, Business Support Services=BSS, Broadcast and Publishing=BP, Cultural Service=CS, Chemical Industry=CI, Construction=C, Energy Generation and Supply=E, Education Service=ES, Finance and Insurance=FI, IT Manufacture=ITM, IT Service=ITS, Light Industry=LI, Mining and Quarrying=MQ, Manufacture of Machinery=MM, Manufacture of Transport Equipment=MTE, Medical and Human Health Service=MHHS, Non-Metal and Metal Industry=NMMI, Others Manufacture=OM, Other Service=OS, Public Administration and Defence Service=PADS, Professional, Scientific and Technical Activities=PSTA, Real Estate Service=RES, Transport Service=TPS, Wholesale and Retail Trade=WRT

and Publishing and Culture Service. Professional, Scientific, and Technical Activities was linked to Broadcast and Publishing. In addition, Finance and Insurance was found to be linked to IT Service.

Overall, most smart city industries were linked to the Chemical Industry, Light Industry, Non-metal and Metal Industry, and other traditional industries. The degree of interconnection among smart city industries was not sufficiently high (Jo, S.S. and Lee, S.H., 2018 and Jo et al., 2021), and clusters that were centered around smart city industries did not exist (Jo et al., 2021). These results can be interpreted to mean that the smart city industry is not a core industry of the economy but serves traditional industries as a subsidiary industry. However, given the overall changes in the smart city industry over time, the smart city industry continues to advance while enhancing its significance, and at the same time, there is an increasing need for this industry to do so.

V. Conclusions

The present study aimed to analyze changes in the network of the smart city industry. Through literature review, the smart city industry was defined to encompass IT Manufacture, IT Service, and Knowledge Service. The industry's network was established using social network analysis (SNA) and minimum spanning tree (MST), and the obtained network was represented using Gephi 0.9.2 and Multi Gravity Force Atlas 2 (MGFA2) algorithms. In the present study, the network structure of the smart city industry was analyzed with respect to in-out degree centrality, closeness centrality, betweenness centrality, and clusters. The analysis results can be summarized as follows.

First, as the density of the industrial network structure increased, the network, which was initially simple, became increasingly complex, and the degree of interconnectivity between industries also increased. It was found that the network structure was most significantly affected by traditional manufacturing industries, among others. Smart city industries were found to involve nodes that were smaller than those of traditional industries. In addition, most of them were located on the outskirts of the network, and thus they were classified as industries with less significant influence. Over time, however, nodes for IT Manufacture and Knowledge started to increase in size and shift toward the center of the network. This suggested that the influence of the smart city industry expanded in a gradual manner. Furthermore, the number of isolated smart city industry nodes decreased over time, but Knowledge Service remained isolated from other industries. This result suggested that content services or knowledge algorithms were not linked to other industries in smart cities.

Second, changes in the in-out degree centrality, closeness centrality, and betweenness centrality of the smart city industry were mainly driven by IT Manufacture and Knowledge Service. The out-degree centrality of smart city industries was found to be higher than the in-degree centrality. In other words, the smart city industry is more likely to directly or indirectly affect other industries rather than being affected by them. The closeness centrality of the smart city industry was found to increase over time. The advancement of the smart city industry was mainly driven by IT Manufacture, but it was found that its structure was vulnerable to collapse when other industries were subjected to external shocks. This indicated that the smart city industry should advance in line with other industries and technology through convergence rather than growing on its own. Simply put, the smart city industry is less likely to grow on its own. The betweenness centrality analysis shows that the role of the smart city industry as a bridge that connects one industry to another is expanding. This result can be interpreted to mean that the smart city industry is gradually transitioning from one that is easily affected by other industries to one that significantly affects other industries.

Third, the number of industrial clusters was higher in 2015 than in 1960, but clusters that were centered around smart city industries were not observed. This suggested that the smart city industry was not the main source of the changes observed in clusters. As of 2015, isolated nodes, which were not linked to any other industries, existed, and the degree of interconnectivity between smart city industries was not sufficiently high. These results were consistent with what was obtained in the network structure and centrality analysis described above. However, a positive signal was that attempts had been made for smart city industries to form clusters centered around IT Manufacture.

In fact, the Korean economy has been mainly driven by manufacturing industries. Thus, these traditional manufacturing industries, traditional services, and the construction sector have been highly influential. Perhaps reflecting this reality, IT Manufacture and Knowledge Service under the category of the smart city industry were found to remain high on the list of centrality. In contrast, however, IT Service was not included on the list or was highly insignificant in all analysis results. Based on these results, the changes made to the network of the smart city industry were considered to be insignificant.

As previously discussed, in Korea, the smart city industry has been pushed forward mainly by IT Manufacture and Knowledge Service. This, however, means that if the country became no longer competitive in this traditional manufacturing sector, its smart city industry itself would possibly collapse because its structure is mainly based on IT Manufacture and Knowledge Service. IT Manufacture and Knowledge Service may be the key industrial sectors that strengthen the entire structure of the smart city industry but, at the same time, negatively affect its growth. Addressing these risks requires more industrial policies to focus on the balanced growth of IT Manufacture, Knowledge Service, and IT Service.

Despite its contributions, the present study has certain limitations which need to be addressed. First, there is more room for improvement in the classification of smart city industries. Many researchers have so far worked on this issue, but a definite solution has yet to be found. Second, industry categories as of 2015 were reclassified into a smaller number of groups, i.e., 25 industry types. Given that the number of small sectors was 165, the scope of analysis should be further extended. Third, it is important to use the latest data. In the present study, the 2015 input-output table (based on actual measurements) was the latest data available for the analysis. If the 2020 input-output table (based on actual measurements) is made available to the public and used for a future study, it will be possible to more accurately analyze changes in the smart city industry. Fourth, a comparison not only with China, Japan, and other neighboring countries but also with the key players in smart cities (e.g., Spain) will be necessary for a better representation of the reality. The major findings of the present study are expected to contribute to determining where Korea's smart city industry stands today while guiding the government's decision-making on industrial policy regarding smart city industry clusters currently under discussion at the national level.

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