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The Strategic Transformation from Innovation Cluster to Digital Innovation Cluster during and after COVID-19

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Abstract It is generally known that a Science and Technology Park – as a representative example of an Innovation Cluster - produces network synergy among industry, university, research institutes, and other innovation actors in a specific area, so that it has a competitive edge over other regions in technological innovation. However, as the novel Coronavirus (COVID-19) pandemic unfolds, it has become necessary to reduce face-to-face contacts and this could lead to lesser network synergy being produced in an Innovation Cluster. With this background, this research was designed and conducted to evaluate how COVID-19 has changed the activities in Innovation Clusters and explore future development scenarios. In order to find out the changes occurring in an Innovation Cluster, a survey was conducted among the people in Science and Technology Parks. The survey result shows that people are experiencing difficulties in technological innovation and support activities, and face-to-face contacts have been reduced in the Innovation Cluster. A scenario planning sought to explore the future development of the Innovation Cluster. It suggests that the transformation into a Digital Innovation Cluster, which is less affected by physical distance, but can still maintain the effectiveness of the networks, can be the key strategy for the future Innovation Cluster.

Keywords Innovation Cluster, Digital Innovation Cluster, Virtual Innovation Cluster, University Industry Research Institute Network, Technological Innovation, Coronavirus, COVID-19

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I. Introduction

Science and Technology Park (STP) is a representative example of an Innovation Cluster. The Innovation Cluster has many characteristics that can be defined as a specific region, where the innovation actors such as a university, a research institute and firm are located closely and innovation activities are actively taking place, which lead to advantages over other regions in innovation (Yim, 2002; 2004; 2014, Yim, et al., 2004). A STP can be competitive over other regions because the interaction among industry, university, and research institute in the specific area generally create a network synergy, so that innovation cost can be lower and tacit knowledge transfer can be easier during the technological innovation process. The synergy occurs in the exchange and combination of funds, knowledge and manpower throughout the entire technological innovation processes, from planning to commercialization of technology. In an Innovation Cluster, the innovation actors, not only collaborate, but also compete with each other generating high level of innovations.

However, the COVID-19 pandemic can nullify such an advantage of Innovation Cluster because it requires people to be socially distanced, with face-to-face contact dramatically reduced, hence, the network synergy in the Innovation Cluster cannot be produced as before. It is also observed that many people have started to use video-conferencing as an alternative to face-to-face meetings. Even if the COVID-19 pandemic situation gets under control, it is questionable whether the Innovation Cluster as it was designed can be reactivated. This kind of deep change leads us to rethink whether the Innovation Cluster is still useful during the COVID-19 period and after. If not, what are the alternatives for the future Innovation Cluster? With this background, this research was designed and conducted to evaluate how COVID-19 changed the activities of the Innovation Clusters and explore future development scenarios.

The objectives of the research are as follows. First, we analyze how the current environment and activities within the Innovation Cluster have changed with the COVID-19. It is assumed that the overall activities in STPs have decreased, especially those related to face-to-face activities and several support activities. Second, we explore the development strategy of Innovation Cluster in the post-COVID-19 future. Even if the COVID-19 pandemic subsides, it is expected that society will not be able to return to the same state as before. Since face-to-face contact is not encouraged and the demand for digital activities has increased, the possibility of a shift to a Digital Innovation Cluster is explored and discussed.

II. Research method

In order to find out the changes in the STPs during COVID-19, a survey was conducted. In the meantime, a review of the relevant literature was undertaken based on the existing documents about Innovation Cluster and the trends related to COVID-19. Finally, scenario planning was carried out to explore the future direction for Science and Technology Parks. The scenario focused on how to evolve into a Digital Innovation Cluster that enables innovation actors to collaborate through digital infrastructure, while face-to-face connections decrease in an Innovation Cluster.

The survey was conducted among professionals, researchers, and managers in the STPs located in South Korea and some other countries. As the COVID-19 pandemic affected our overall economies, it is hard to predict the effects with traditional methods, hence various scenarios were contemplated for the future development path of STPs. This research is exploratory, based on a survey and scenarios, and attempts to predict the evolution of STPs to Digital Innovation Cluster in the future with various assumptions.

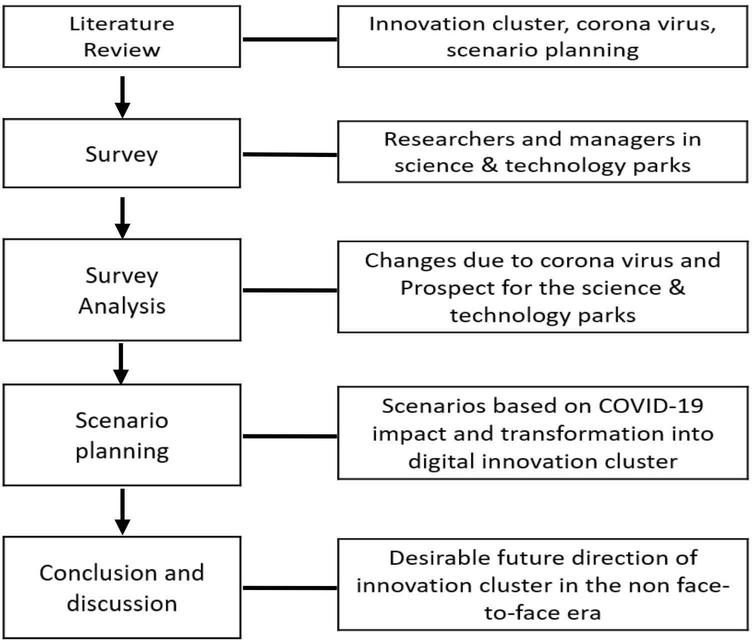

Figure 1 Flow of research

III. Literature review

1. Impact of COVID-19

In this section, a review of literature related to COVID-19 impacts, Innovation Cluster, and Scenario Planning is conducted. For COVID-19-related issues, various documents are available from a wide variety of fields, including those on the causes and treatment of infectious diseases and on the prevention of epidemics. There are also many research papers and documents on vaccine and treatment development, but as this is not within the scope of this research, they are not reviewed. The literature dealing with socioeconomic phenomena related to COVID-19 are examined.

It is clear that COVID-19 has strongly influenced political, economic and social aspects. The World Bank president estimated that about 60 million people would directly fall into extreme poverty, living on a daily income of less than $1.25 (World Bank, 2020). Also, with the rise of the non-face-to-face economy (Untact economy), the digital economy is expected to emerge fast. In addition, it is expected that political strife will intensify and digital democracy will spread due to the distrust of government and politics (Samil PwC, 2020). Non-face-to-face work and digitalization will be accelerated, especially in the areas of finance, services, distribution, leisure, etc. In the field of education, the spread of on-line lectures has also raised fundamental question about whether the existing university system is appropriate. The Ministry of Education and the Ministry of Science and ICT in Korea are working together on communication infrastructure and equipment to establish a remote education environment for remote learning. (Ministry of Science and ICT, 2020).

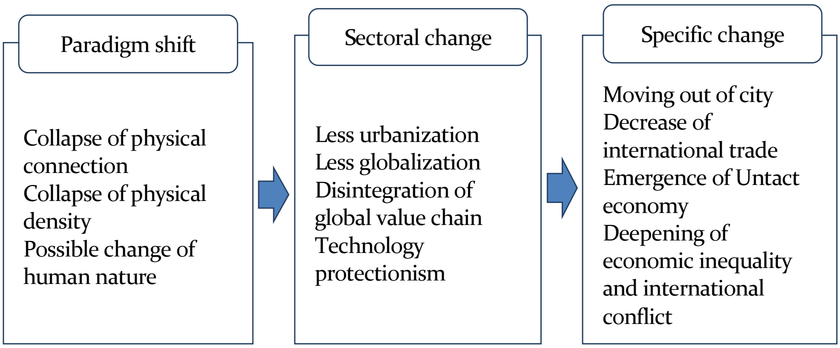

Figure 2 Logical framework to understand changes caused by COVID-19

These various COVID-19-related economic and social effects are both direct and large, but can be understood in the following framework: first of all, a paradigm shift or a very fundamental change. It is a kind of paradigm shift where the nature of the COVID-19 pandemic reduces people-to-people encounters. As a result, the crowded environment, such as meetings and events decrease and non-face-to-face meetings increase. Some predict that the city's population density will decrease as those who are able to, will leave the city.

Given that human nature is social, the fundamental question arises whether the phenomenon of connecting via face-to-face will decrease. If human nature does not change, the fundamental issue is how to cope with the decline in physical connectivity without reducing psychological connectivity. A possible solution may be that enhancing digital connectivity will offset the effect of reducing physical connectivity. Whether psychological connectivity through digital connections will be maintained or strengthened will be clear only after a long period of experimentation and finding out whether human nature is changing.

2. Innovation Cluster

2.1 Geographical Innovation Cluster

The concept of Innovation Cluster is useful to understand STPs. The discussions on geographical clusters first started when Alfred Marshall presented a new concept called an industrial district in his 1980 book "Principles of Economy" (Kim S. et al., 2005). Since then, it has been actively discussed by scholars of economic geography and regional economics, who referred to the concept as a new industrial space or a regional innovation environment. Later, the concept of a geographical cluster emerged as a key policy theme in the early 1990s, as Michael Porter introduced the cluster concept, and various studies confirmed the growth of global industrial clusters like Silicon Valley, following an experimental study on the industrial districts of the Third Italy in the early 1980s (Kim, et al., 2005). Attention to the cluster policy increased significantly in 1999, when OECD started to mention "innovation cluster" as one of the key themes of the national innovation system (NIS). OECD spearheaded studies on clusters by selecting the innovation cluster concept as its key research topic for the NIS project and forming a focus group for studying innovation clusters (OECD, 1999, 2001).

A geographical cluster has been conceptualized by various scholars from diverse academic backgrounds. Its general definition is a cluster formed through geographical concentration of various organizations (Martin & Sunley, 2003; Preissl & Solimene, 2003; OECD, 2001). This definition has been used as a broader term to refer to industrial and innovation clusters (Kim, 2016). An industrial cluster means "a state of firms concentrated in a certain geographical area, whose businesses are interconnected through cooperation and specialization in the value chain of a specific industry." An innovation cluster refers to "a state of innovation actors (e.g., firms, universities, research institutes, business support organizations, and financial institutions) located in a certain area or space forming a mutual cooperation system" (Jang, 2004). These two concepts share a commonality since they both require geographical concentration as a prerequisite. However, they are different in their focus as the former emphasizes the inter-connectivity of industries or firms, while the latter pursues to build a comprehensive system, not only covering specific industries or firms, but also their knowledge creation and dissemination activities (Jang, 2004).

Table 1 The Concept of Geographical Cluster

Term	Concept
Industrial cluster	A state of firms concentrated in a certain geographical area, whose businesses are interconnected through cooperation and specialization in the value chain of a specific industry. To emphasize the inter-connectivity of industries or firms.
Innovation cluster	A state of innovation actors (e.g. firms, universities, research institutes, business support organizations, and financial institutions) located in a certain area or space forming a mutual cooperation system To pursue to build a comprehensive system not only covering specific industries or firms but also their knowledge creation and dissemination activities.

Source: Kim (2006), p. 36

Despite varying definitions of geographical clusters by scholars depending on their academic background, they share the following four common features (Kim, 2006). First, clusters are formed in a geographical proximity though their scale that may vary from cities to mega-cities or even global entities (Bekar & Lipsey, 2002; Asheim et al., 2006; Malmberg & Power, 2006; Niosi, 2000). Second, clusters represent a concentration of various innovation actors such as firms, universities, government research institutes and other supporting organizations capable of offering technology and business-related infrastructure (Bekar & Lipsey, 2002; Asheim et al., 2006). Third, participants to the clusters are linked together (Asheim et al., 2006; Malmberg & Power, 2006). Strong formal and informal linkages exist between all the stakeholders including firms, universities, government research institutes, and other technology and business supporting organizations, which share not only commonalities, but also complementary assets. Fourth, clusters are self-sufficient; clusters tend to supply key inputs in need from their inner suppliers. So, the bigger the size of a cluster, the higher the possibility of its self-sufficiency (Preissl & Solimene, 2003).

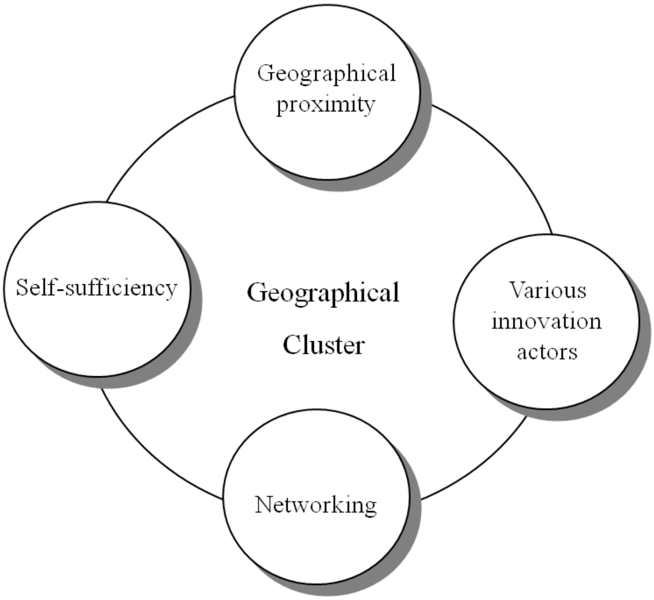

Figure 3 Characteristics of Geographical Cluster

Source: Kim (2006), p. 40

In the Geographical Innovation Cluster theory, the view is that geographical proximity and advantage of particular region could increase the competitiveness of STP as an Innovation Cluster. The theory views that STPs could have a competitive edge over other regions because networks are formed among university, industry, and research institute networks with geographical proximity and create a synergy in the technological innovation process. For instance, Cho (2014) argued that, as the result of the policy of fostering Innovation Cluster, integration and consolidation through the formation of mini-clusters are centered on companies within the Innovation Cluster in Korea, which means that they were aware of the effects of reducing transaction costs, motivating technological development, and enhancing productivity in Innovation Cluster. Meanwhile, the Innovation Cluster policy emphasizes the creation of a support system and an open operating system in which the informal forms of networks can be activated, focusing on software aspects such as social capital. In other words, synergy is emerging in the Innovation Cluster because of reduced transaction costs and increased productivity over the network.

Although the network effects of Innovation Clusters are difficult to measure and there is limited research, most experts tend to recognize these network effects. Even though there are various names of STPs such Science parks, Technovalley or Innopolis, they all can be regarded as a kind of Innovation

Cluster. The Innovation Cluster can be classified from various perspectives, including the cause of the Innovation Cluster formation, its creator, its main functions, its major industries, and its size, while analyzing the Technological Innovation process in detail (Yim, 2014)[1].

2.2 Virtual Innovation Cluster

Geographical Innovation Clusters based on physical concentration are bound to have innate limitations. Against this backdrop, a new concept called Virtual Innovation Cluster emerged in the late 1990s as an alternative to geographical clusters (Kim, 2006). This new concept of Virtual Cluster based on virtual concentration was invented to overcome the limitations of geographical clusters (Kim, 2006).

In the concept of Virtual Innovation Cluster, the STPs are based on the use of information and communication technology for their activities. In the Innovation Cluster concept, a specific region and networked innovation actors are assumed. In contrast, Virtual Innovation Clusters refer to 'virtual networks in which various innovators, such as university, industry, research institute, and networks, utilize Information Communication Technology (ICT) to facilitate innovation activities, such as creating, sharing and utilizing knowledge, regardless of physical distance' (Kim, 2006). In South Korea, some projects (e-cluster projects) aimed at virtual clusters have been assessed to be insufficient, including simple information-oriented services, low utilization, poor network effects, lack of value chain complementary features, insufficient network brokers' activities and capabilities, and lack of online and offline connectivity (Kim, 2006).

2.3 Digital Innovation Cluster[2]

The existing literature argues that the STP is one of the representative Innovation Cluster, which can be developed into Virtual Innovation Cluster. In this research, the authors present Digital Innovation Cluster (DIC), which encompasses the concept of Virtual Innovation Cluster in the digital era. Digital Innovation Cluster is characterized with the following key features. First, DICs presume a digitally-configured virtual space, while geographical clusters are preconditioned on geographical space. Unlike geographical clusters, DICs enable networking and value creation in a virtual space with the use of various

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[1] In this sense, the Science and Technology Park and Innovation Cluster are used interchangeably.

[2] In the beginning, the concept of Virtual Innovation Cluster is used in the survey. As the research is progressed, it is found out the concept is not readily understood by the people and the concept of Digital Innovation Cluster is more accurate to show future STP picture in digital era. So, the Digital Innovation Cluster is used

technologies such as virtual reality, big data and cloud computing, virtual conferencing, virtual training, and blockchain technologies.

Second, Digital Innovation Cluster is configured in a web-based Internet environment unlike geographical clusters, which pursue networking through face-to-face interactions. Third, Digital Innovation Cluster emphasizes the roles of Internet service providers in addition to those of innovation actors like industries, universities, research institutes, government, and other supporting organizations. Since Digital Innovation Cluster presumes a web-based environment like the Internet environment, it requires various web-based services providers who can help build and operate such web-based environment. Fourth, Digital Innovation Cluster often relies on rules and standards as a mechanism to control cluster members, while geographical clusters value a trust-based culture. Unlike geographical clusters, Digital Innovation Cluster needs to enact a series of rules and standards that can be enforced in a web-based environment to effectively control remotely-located cluster members or actors. Lastly, Digital Innovation Cluster is also self-sufficient and path-dependent like geographical clusters. As Digital Innovation Cluster strives to serve certain industries' needs for value chain functions in a virtual space, cluster members' innovation capacity accumulated over a certain period of time is bound to have a lasting impact on their business execution.

Table 2 Comparison between Geographical Cluster and Digital Innovation Cluster

	Geographical Cluster	Digital Innovation Cluster
Agglomeration space	Geographical space	Digitally configured virtual space, Use of various technologies of the Fourth Industrial Revolution
Network base	Face-to-face interaction, Social capital	Web-based Internet environment, Nonsocial capital
Actors	U-I-R-G[3], etc.	U-I-R-G, etc. + Internet Service Provider
Control mechanism	Trust and culture	Rule and standard

Source: Kim (2006), p. 65 revised

[3] U-I-R-G is University, Industry, Research Institute and Government

3. Scenario Planning

The final set of literature reviewed is about the concept of scenario planning. Scenario planning is basically a strategic way of responding to the future by creating scenarios with multiple assumptions as the variables are complex in predicting the future. According to Choy (2020), both advantages and limitations exist in the scenario planning method. It can induce the participation of different stake-holders at different levels in the process of scenario planning and improve the decision-making process by collective intelligence. However, there may be some people who do not participate in collective opinions leading to disadvantages such as predicting a future too limited, or taking much time and resources to gather diverse opinions.

Scenario planning methods could be divided into exploratory and normative ones. The two methods differ in approaches. The exploratory method explores the future by assuming various changes in circumstances as a way of finding answers to the question “What will happen?” By contrast, a normative approach sets up a future object and then sets up a scenario on how to get there (Yim, Han and Jeong, 2009).

The literature on the scenario planning shows that it can be used to predict or simulate various alternative future pictures even though it has some limitations. Considering the volatile characteristics of COVID-19, it would be worthwhile applying the scenario planning method to explore the future direction of STP.

IV. Details of the Survey

1. Survey Aim

As described earlier, Innovation Clusters are known to have strengths in the technological innovation by interacting with innovation actors in close proximity. This survey was intended to find out the situation experienced by STPs and related agencies due to the COVID-19 pandemic and the future direction of the post COVID-19 environment that the organizations’ members expect. The survey asked also about the possibility of Virtual Innovation Clusters in the non-face-to-face era.

The survey questionnaire was distributed to various people among the organizations in Sciences and Technology Parks located both in South Korea and other countries. It was composed of short questions ranging from influence of COVID-19 to the future strategy for STPs.

Table 3 Contents of the survey questionnaire

Respondent information	· Nationality, Affiliated Science Technology complex, Occupation, E-mail
Influence of COVID-19	· Face-to-face communication ·Non-face-to-face communication · Event ·Collaborative research and cooperation · Demand for Innovation activity and support ·Finances · Technological innovation environment of organization. · Affiliated Science & Technology Park's technological innovative environment ·Support area (multiple choice)
Strategy and Direction of Post COVID-19	· Non-face-to-face factors ·On-line activities · Method of Cooperation for Innovation · Strategy and Direction of Technological Innovation and Supporting · Supporting areas expected to be reduced after COVID-19 (multiple choice) ·Other expected strategy direction
Virtual Innovation Cluster	· It will be transformed into virtual Innovation Cluster in the future. · Productivity of Virtual Innovation Clusters on STPs ·others

The survey was conducted using e-mail with Google Survey link as follows.
- Survey period: May 15, 2020 to May 23, 2020
- Measure: 5-point Likert scale choice or essay question

2. Survey Results

2.1 Impact of COVID-19

It was found that face-to-face communication, various events, joint research, and cooperation in the Science and Technology Parks were reduced, and the technological innovation environment was perceived as worsened (Table 4). However, the support requests and funding support in Science and Technology Park have not decreased significantly, which suggests that public support in STP appears not to be affected that much. In addition, the responses indicated that non-face-to-face elements or the online event in the STPs have increased. However, the response that cooperation will decrease seems to reflect the nature of STP, which encourages the interaction of innovation actors. As for the transformation into a Virtual Innovation Cluster, people think it will be likely.

Table 4 The Impact of the Science and Technology Parks on COVID-19 and Future Strategies

Effects of COVID-19 on STPs	Average	Standard deviation
- Decrease in face-to-face communication	4.31	0.77
- Increase in non-face-to-face communication	4.46	0.68
- Cancellation or reduction of events (seminars and workshops)	4.42	0.78
- Decrease in joint research or cooperation with other innovators	3.62	0.87
- Decrease in support request from the actors in STP	2.96	1.08
- Decrease in funding support in STP	2.86	1.07
- Increase of difficulty in the technological innovation environment of affiliated organization	3.15	0.94
- Increase of difficulty in the technological innovation environment of affiliated STP	3.22	1.00
Strategy and Direction of after-COVID-19		
- Increase of Non-face-to-face Element	4.38	0.61
- Turning to online events such as seminars and workshops	3.96	0.89
- Independent activities in Technological Innovation rather than cooperation with other innovation actors	2.87	1.00
- Affiliated organization's Technological innovation and Strategy, Direction of the Supporting were changed significantly.	3.51	0.90
Shift to Virtual Innovation Cluster		
- It will be transformed into virtual Innovation Cluster in the future.	3.72	0.96
- Virtual Innovation Cluster will increase the productivity of STPs	3.61	0.93

* Notes: a scale of 1 to 5, with 1 being Strongly Disagree and 5 being Strongly Agree

STPs are being established in various forms around the world. The impact of COVID-19 may be different in each country because the operation, support content, strategies to support the innovation are different. In this study, comparison analysis between South Korea and other countries are done.

Table 5 The Impact of COVID-19 on STPs between Korea and other countries

	Group	Average	Standard Deviation	P-value	Remark
Effects of COVID-19 on STPs					
Decrease in face-to-face communication	Korea	4.21	.822	.049	P<0.05
	Non-Korea	4.51	.607		
Increase in non-face-to-face communication	Korea	4.39	.720	.082	P<0.1
	Non-Korea	4.62	.545		
Cancellation or reduction of events (seminars and workshops)	Korea	4.61	.584	.001	P<0.01
	Non-Korea	4.00	.972		
Decrease in joint research or cooperation with other innovators	Korea	3.71	.889	.076	P<0.1
	Non-Korea	3.41	.798		

Decrease in support request from the actors in STP	Korea	3.04	1.049	.238	*
	Non-Korea	2.78	1.134		
Decrease in funding support in STP	Korea	2.73	1.043	.039	P<0.05
	Non-Korea	3.16	1.068		
Increase of difficulty in the technological innovation environment of affiliated organization	Korea	3.31	.880	.007	P<0.01
	Non-Korea	2.81	.995		
Increase of difficulty in the technological innovation environment of affiliated STP	Korea	3.45	.926	.000	P<0.01
	Non-Korea	2.73	.990		
Strategy and Direction of after-COVID-19					
Increase of non-face-to-face element	Korea	4.38	.624	.978	*
	Non-Korea	4.38	.594		
Turning to online events such as seminars and workshops	Korea	3.86	.838	.115	*
	Non-Korea	4.16	.986		
Independent activities in Technological Innovation rather than cooperation with other innovation actors	Korea	2.80	1.024	.253	*
	Non-Korea	3.03	.928		
Affiliated organization's Technological innovation and Strategy, Direction of the Supporting were changed significantly.	Korea	3.46	.885	.374	*
	Non-Korea	3.62	.924		
Shift to Virtual Innovation Cluster					
It will be transformed into virtual Innovation Cluster in the future.	Korea	3.70	.920	.768	*
	Non-Korea	3.76	1.065		
Virtual Innovation Cluster will increase the productivity of STPs	Korea	3.58	.952	.588	*
	Non-Korea	3.68	.884		

Note: * means not statistically significant and P-value means P-value in T-test.

Table 5 shows that the decline in face-to-face communication and the increase in non-face-to-face communication were relatively higher in other countries than in South Korea. It can be explained partially by the fact that South Korea has been responding relatively well in the prevention of the COVID-19 and maintained face-to-face meeting to some extent. The survey also shows that the limitation or canceling of various events and the reduction in joint research or cooperation with other innovation actors have more affect in South Korea than in other countries, and it may be because the South Korean government discouraged such activities. The difference in support request between South Korea and other countries is not statistically significant. The peculiarity is that the perception about reduction in supporting fund was higher in other countries, but Korea's respondents perceived that the technological innovation environment was more difficult than in other countries. There was no statistically significant difference on the responses to the six questions related to the post-COVID-19 strategy and direction of the STPs, and the changes to the Virtual Innovative Cluster.

2.2 The impact of COVID-19 in supporting activities in STP

The survey asked how much the supporting activities in STP are affected by COVID-19. The supporting activities are divided into education and training, pilot production, R&D, equipment provision, information supply, business incubation, and others. In addition, which supporting activities will be increased or decreased in the future after COVID-19 is examined.

Table 6 Supporting Business reduced by COVID-19

	Total		Korea		Non-Korea	
	Respondent	%	Respondent	%	Respondent	%
Space provision	46	20%	35	22%	11	15%
Education and training	83	35%	67	42%	16	22%
Pilot production	16	7%	8	5%	8	11%
R&D	24	10%	15	9%	9	12%
Equipment providing	24	10%	9	6%	15	20%
Information supply	4	2%	4	2%	-	-
Business incubation	33	14%	19	12%	14	19%
Others	4	2%	3	2%	1	1%
Total	234	100%	160	100%	74	100%

Note: Others mean networking, meetings, non-domestic marketing support, and benchmarking activities.

The most areas where support was reduced include education and training, followed by space provision and business incubation. In non-South Korea countries, education and training, equipment provision, business incubation, and space provision were reduced in that order. From the survey, it is evident that the activities will be decreased in the following order: education and training, space provision, equipment providing, and business incubation in the STP, after the COVID-19 crisis. In some comments, people see that the education and training will increase with the transition to the non-face-to-face approach. In South Korea, it is expected that the information supply followed by R&D will increase after the crisis. Overseas respondents are also expecting that the information provision and education and training will be increased. It can be inferred that the digital environment is coming fast and increase the non-face-to-face business.

Table 7 Supporting Business expected to be reduced after Corona Virus

	Total		Korea		Non-Korea	
	Respondent	%	Respondent	%	Respondent	%
Space provision	57	24%	40	25%	17	23%
Education and training	70	30%	60	38%	10	13%
Pilot production	18	8%	9	6%	9	12%
R&D	10	4%	7	4%	3	4%
Equipment providing	39	17%	23	14%	16	22%
Information supply	7	3%	2	1%	5	7%
Business incubation	23	10%	12	8%	11	15%
Others	10	4%	7	4%	3	4%
Total	234	100%	160	100%	74	100%

Note: 1) Education and training is rather transformation into non-face-to-face way than actual decrease in quantity.
2) Others mean exchanging information, supporting non-domestic marketing, establishing an Overseas network, marketing, face-to-face events, seminars, workshops, and field trips.

Table 8 Support areas expected to expand after COVID-19

	Total		Domestic		Overseas	
	Respondent	%	Respondent	%	Respondent	%
Space provision	8	3%	3	2%	5	7%
Education and Training	24	10%	9	6%	15	20%
Pilot production	19	8%	10	6%	9	12%
R&D	62	27%	50	31%	12	16%
Equipment providing	13	6%	10	6%	3	4%
Information supply	69	30%	54	34%	15	20%
Business incubation	29	12%	18	11%	11	15%
Others	10	4%	6	4%	4	6%
Total	234	100%	160	100%	74	100%

Note: Others mean non-face-to-face collaboration and technology development, non-face-to-face events (seminar, workshop), information provision, re-start-up, attracting investment, new concept marketing, online non-face-to-face communication and education support platforms, automation/robot, market/funding support, and online events.

2.3 The emergence of Virtual Innovation Cluster

The Virtual Innovation Cluster (Kim, 2006) is defined as a virtual network in which the close interaction among innovation actors, create synergy and produce innovation activities by utilizing ICT. Many respondents replied that Science and Technology Parks would be transformed into a Virtual Innovation Cluster in the non-face-to-face era, which could increase the productivity of the STP. And it is notable that the majority of respondents, who provided descriptive and other opinions on the expanding support area of the Science and Technology Parks, replied that non-face-to-face business will become more prominent in education, meetings, research planning, and that R&D will be increased in the non-face-to-face industry. However, further research will be needed as this survey is not specifically designed for the Virtual Innovation Cluster and non-face-to-face business.

Through this survey, it is found out that STPs and Innovation Clusters around world are experiencing difficulties in overall support activities for the innovation, and various support activities using face-to-face contact have been reduced, in particular. The COVID-19 crisis is causing the change in the strategy and direction of technological innovation and support, and after the COVID-19, non-face-to-face elements will increase, and R&D, information supply, and education and training support using the digital environment will become more prevalent. As a result, cluster policies will be required to promote the research and development in non-face-to-face-related business, or to move into Virtual Cluster that facilitates information supply and education and training business using digital environment. In addition, enabling networking among Innovation Clusters can be considered as well as activating cluster networking using digital technology in the areas of education and training, information supply, and joint research and development.

V. Scenario Planning

1. Scenario planning method

Scenario planning can be divided into exploratory method and normative method. In this study, these two methods were used simultaneously. In other words, scenarios for environmental changes caused by COVID-19 and building Virtual Innovation Clusters that can have network effects in a non-face-to-face approach are considered in an integrated manner. There might be several ways to create a scenario, but generally the following steps are required (Schoemaker, 1995).

- Analysis scope setting: time, technology change, competitive strength, etc.
- Defining key stake-holders: customers, management, society, etc.
- Identifying major trends: direction and degree of change in politics, economy, technology, society, and legal system

- Identifying key uncertainties: the events or results which will affect the uncertainty
- Creating an initial scenario: create a scenario based on two extreme assumptions
- Checking the consistency of the scenario and the degree of explanation satisfaction
- Preparation of learning scenarios: supplementing and selecting initial scenarios
- Additional research needs confirmed: additional research needs identified
- Building a quantitative model: completing a quantitative model that can measure the results
- Evolution to decision stage: final process of decision making by scenario

In this research, an intuitive and simple scenario was created rather than a detailed scenario for corporate or government decisions. Some of the processes were abbreviated to include:

- Scope of analysis: mid-long-term trends before and after COVID-19, changes in innovation activities centered on science & technology parks, changes in technology, intensity of competition, etc.
- Key stake-holders: customers, executives, society, etc.
- Key flows: changes the Innovation Environment
- Core uncertainty: the persistence of the COVID-19 and the possibility of rapid changes in the political economy.
- Creating a scenario: scenario based on changes in the political economy and the degree of response to the science & technology park.
- Scenario inspection and decision making: proposing a plan to develop a science and technology park.

2. Shifts caused by COVID-19

There is a great deal of literature on changes in the situations and how to respond to the COVID-19. It is not easy to measure the effects of COVID-19 because it has a huge impact on almost every sector of our lives, politics, economy, and so on. Nevertheless, the literature on COVID-19 can be classified in two categories. The first is about medical or health content associated with the cause, prevention, and cure of COVID-19. It is expected that the COVID-19 pandemic will not be overcome soon and people have to live with the virus for some time. However, this literature is not evaluated deeply because it is not related with the research purpose.

The second category deals with the socio-economic changes caused by COVID-19. There are basic paradigm shifts and various changes occurring in different fields to be considered. Since the COVID-19 infection occurs via people contact, it will not be possible to avoid COVID-19 as long as people contact each other. Therefore, the physical connectivity among people has to be reduced. In addition, the political and economic activities are based on people's physical connection and movement of goods and services. The globalization of supply chains, and trade and travel are being based on physical connectivity at the global level. However, as this physical connectivity has to be reduced, the opposite phenomenon is happening: people start to have a growing antipathy toward globalization, and this lead us to predict de-globalization and less-urbanization. (Garrett, 2020)

Economically speaking, the traditional face-to-face (contact) industry is in trouble, while the non-face-to-face industry is growing (Samil PwC, 2020). In the future, with the U.S. and China in conflict, the existing division of innovation, production and consumption into international division of labor will develop into an unstable, multipolar global value chain (Kim, 2020). Meanwhile, there are also problems in controlling and managing personal information in quarantine activities using Digital Technology. This will also amplify the discussion of which national-level political system is good (Yim, 2020).

Table 9 Changes caused by the COVID-19

Field	Contents
Medical & Health	- Efforts to develop vaccine and medicine - Increase in the tele-healthcare system.
Economy	- Collapse of global supply chain - Rearrangement of regional economic bloc around United States and China - Decline of service industries such as aviation, transportation and restaurants. - Growth of non-face-to-face business such as remote education, shopping, and medical service
Politics	- Conflicts due to the international dispute over the responsibility on COVID-19
Society	- Less-urbanization - Widening gap between the rich and poor
Environment	- Improved environment due to decreased energy consumption

3. Planning scenarios

The unprecedented COVID-19 pandemic has led to many changes, and in the process of these changes, a window of opportunity is opening while there are risks. The fourth industrial revolution using artificial intelligence or big data may come sooner and faster than expected. The basic assumption is that the impact of COVID-19 will be negative for the STPs because the network synergy among innovation actors will be reduced. One way to overcome COVID-19 in STPs is to go for Digital Transformation to maintain the network synergy even though face-to-face contact has to be reduced.

In creating the scenarios, two main criteria are used. The first is the impact of change that COVID-19 will bring. As we look ahead, the change is occurring in all areas of politics, economy, and society. And there is a possibility that it will continue for a long period of time, until a medicine or vaccine is developed. The scenario will vary depending on whether the impact will stop or continue to grow in the extent that it has been experienced so far.

The second criterion is the capacity and response of STPs in deploying the strategy of Digital Transformation. Digitalization is the way to create network effects while reducing non-face-to-face contact. Hovsepyan (2020) stresses that the EU's digital strategy, which has been pursued at the EU level, is basically in line with its COVID-19 response (https://www.e-ir.info). Kim (2006) argued that Virtual Innovation Clusters can perform better than existing Innovation Clusters by utilizing ICT and he suggested strategies to promote Virtual Innovation Clusters. Both Digital Innovation Cluster and Virtual Innovation Cluster are based on ICT technology and can go beyond physical distance barrier. In this sense, they can be used interchangeably. However, the Digital Innovation Cluster will be used more because it is easier to understand.

Table 10 Scenarios of STPs in Response to COVID-19

COVID-19 Impact Long period / Big	<Scenario 3> Falling behind	<Scenario 4> Maintain current level of competitiveness
COVID-19 Impact Short period / Small	<Scenario 1> Maintaining current status or losing the relative competitiveness	<Scenario 2> Securing relative competitiveness
	Digitalization of STP, Slow / Passive	Digitalization of STP, Fast / Active

Note: The scenario was formulated and discussed by the authors and get reviewed in the colloquium of International Society for Innovation Cluster in July 2020

The scenarios can be split into four different ones. The Science and Technology Parks, which falls under <Scenario 1>, is likely to remain the same as it is today or lose relative competiveness. If there is not active response with digitalization at a time when productivity is declining due to the COVID-19 crisis, it will have no choice, but to backtrack compared to other parks. The worst scenario for STP is the <Scenario 3>. If the STP in question is not strategically pursuing digitalization and the impact of COVID-19 is big, the productivity in the parks will be very low. In this case, it should be regarded as a failure.

The cases of active digitalization of the STPs are <Scenario 2> and <Scenario 4>. <Scenario 2> is the most desirable scenario for the STP. By preemptively achieving digitalization, the park can be more productive and secure competitiveness. <Scenario 4> seems to be able to maintain a minimum current level of competitiveness. The negative effects of COVID-19 could be offset or overcome by the digitalization.

These scenarios could be wrong if the assumption is not correct. First of all, the evolution of COVID-19 itself is hard to predict. This scenario itself may become meaningless if it becomes relatively easy to develop COVID-19 vaccines and treatments, or the pandemic continues for a very long time. The second is that the digital transformation of STP is not easy as assumed. In addition, if the digitalization is focused only on ICT hardware, and as seen in smart cities, the digital transformation of STP would not bring the expected increase in productivity. Digital transformation requires changes in soft part such as the capacity to utilize ICT and organization and management of the STP, which requires cultural and behavioral changes.

VI. Conclusion and Implications

The recent COVID-19 pandemic is affecting all aspects of our lives. Not only health and medical care, but the socio-economic areas are severely affected globally as well. The activities in STPs are also very much affected. In this background, the research analyzed the effect of the recent COVID-19 pandemic on the Science and Technology Parks and the direction of future STP. For this, literature review, survey, and scenario planning activities were carried out. The survey shows that many activities, especially the face-to-face activities and the support activities in STPs are decreasing and STPs are facing difficulties in technological innovation-related activities. In scenario analysis, it is predicted that the STPs, which are transformed to Digital Innovation Cluster, would overcome COVID-19 and secure relative competitiveness.

For an STP to transform itself to a Digital Innovation Cluster, it is necessary to invest on hardware infrastructure focused on information and communication technology (ICT). The individual innovation actors such as university, industry, and research institute have to embrace the digital transformation environment and change their working style and management system.

This research has some limitations. For instance, there is the possibility that the assumptions in the scenario, especially the development of COVID-19, could evolve differently. It is hoped that further research is carried out with a detailed survey and through scenario analysis. Nevertheless, this research is meaningful in that it is the first one to evaluate the activity changes in STPs in the age of COVID-19 and explore the future scenario in the age of untact society. It is expected to be of great help to policy-maker and working-level managers of STPs, given that they have sought the direction for each scenario. In particular, it is hoped that the theme of Digital Innovation Clusters will be a new paradigm for STPs in the future. The authors hope that the results of this study will contribute to the development of STPs.

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