Ph.D. Dissertation of Engineering

The Effects of Lifecycle Change, Amenities, and Mixed-Use Environments on the Success of Industrial Clusters

생애주기 변화, 도시시설과 복합용도 환경이
산업 클러스터의 성공에 미치는 영향

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Graduate School of College of Engineering
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Abstract

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Industrial clusters are crucial economic pillars for regions, cities, and nations, providing a business-friendly and cost-effective environment and promoting growth and employment opportunities. Industrial clusters can fail or deteriorate, causing unemployment, inefficient land use, and financial loss. Industrial clusters have declined due to challenges from environmental changes, global economic crises, obsolescence, and failing industries. To promote the success of industrial clusters, this dissertation examines the industrial cluster, analyzing characteristics, status, and factors for inclusive decision-making, adaptability, and resilience through holistic approaches from inside of clusters and outside of the clusters. This dissertation comprises five chapters, and each chapter of the body is a stand-alone paper concentrating on sub-research themes with its own research purpose, methodology, site, and results.

Paper 1 (Chapter 2): The Rise and Fall of Industrial Clusters: Experience from the Resilient Transformation in South Korea

Clusters facing crises could have devastating effects on the economic conditions of the regions. Therefore, it is important to study how resilience works in the lives of clusters. The purpose of the current study is to more quantitatively understand the life paths of the growth and decline of industrial clusters by verifying actual patterns. This study explicates the reasons for the formation of these patterns by qualitatively analyzing the process of utilizing resilience. The main contribution to the field of the lifecycle of clusters is the evidence provided to support theoretical concepts on industrial clusters based on data from all the official industrial clusters in South Korea. Although previous works have attempted to define clusters' life paths by classifying them into groups, most studies have dealt with only one or two cases, making it difficult to generalize a theory that can explain all types of clusters. This study used South Korean data as representative data for classification by analyzing the 1,375 industrial clusters for 20 years. The trend of their life paths was calculated using a classic time-series decomposition method, and dynamic time series warping was adopted to measure the similarity between the paths. The k-medoids method from an unsupervised machine learning technique was adopted to classify the clusters into three types: Malmo-type, Silicon Valley-type, and Detroit-type. The same classification method can be applied in other countries looking into promoting the success of their industrial clusters. The classification reveals necessary and weak determinants of resilience in the clusters. Addressing these shortcomings can support and drive the continuous growth of industrial clusters.

Paper 2 (Chapter 3): The Role of Amenities in Cities for Employment Growth of Industrial Clusters: Evidence from a Panel VAR Model

In Chapter 3, the industrial cluster's success is analyzed in the context of a city. Industrial clusters are critical economic drivers of city growth. The typical response to the decline of an industrial cluster focuses on investments within the cluster, such as financial support, the enhancement of aging infrastructure, and road expansion. However, long-term growth is difficult to attain with temporary prescriptions injected only within the cluster. This is because industrial clusters interact with and are affected by the city's development. Cities play an important role in industrial clusters because they serve employees' needs that industrial districts cannot provide for, yet this relationship has not received sufficient attention. Therefore, this study investigates the interrelationships between clusters and their city settlement characteristics, and specifically how the latter characteristics influence one another to lead to cluster employment growth. This study expands on ideas about the role of cultural amenities in industrial clusters that lack sufficient accessibility. It uses panel vector autoregressive methodology to investigate 706 industrial clusters and their 160 cities in South Korea over 10 consecutive years. Cultural amenities can act as a starting point linked to cluster employment growth, prompting the building of other amenities. They also influence the influx of additional facilities to cities, with their overall quality upgraded, resulting in regions with rich amenities. This study suggests strategies for increasing employment in clusters experiencing a lack of employees.

Paper 3 (Chapter 4): How Does Mixed-Use Development Enhance Industrial Clusters' Competitive Edge? Environmental Satisfaction, Social Capital, and Work Performance

Chapter 4 presents an analysis of the growth effect of the mixed-use environments within the industrial cluster. The development of industrial clusters that include amenities for people to "live, work, play, learn, and create" has become increasingly popular worldwide. Mixed-use development is a critical issue in an industrial cluster because it influences the land use plan, attractiveness, and economic growth of the cluster. This study aims to examine how mixed-use industrial clusters affect the success of industrial clusters, including environmental satisfaction, social capital, and work performance. While planners have long recognized the value of mixed use in promoting benefits for workers and firms, the effect of mixed-use has been the subject of extensive debate in the prior literature. The research site is Busan, the second largest city in South Korea, which has different degrees of mixed-use industrial clusters. This research surveyed and employed the structural equation model, and entropy, the degree of mixed-use, was measured using all types of individual buildings in industrial clusters. According to the structural equation model results, entropy directly increases social capital and environmental satisfaction and indirectly affects perceived work performance. This study further suggests the factors that should be considered in planning mixed-use industrial

clusters for sustainable growth: 1) worker preference; 2) building uses, density, and size; and 3) distance from the downtown areas. This study addresses the growing demand for research on the development of mixed-use industrial clusters, recognizing mixed-use development as the key factor influencing an industrial cluster's competitiveness.

This dissertation has important implications for urban planners, policymakers, researchers, and businesses by enhancing industrial cluster performance and sustainability through efficient spatial organization, land allocation, increasing employment, and fostering thriving industries. This dissertation makes a profound contribution to the literature, providing additional theoretical and statistical evidence to support establishing new regulations. Stakeholders can apply insights from this dissertation to evaluate the current status of industrial clusters, strengthen pertinent weakness, and avoid failure. Further, this dissertation adopted methodologies and data, producing abundant evidence for promoting the success of industrial clusters. The findings of this dissertation have ramifications that extend beyond South Korea and can be applied to industrial clusters in other countries.

Keywords: industrial clusters, lifecycle, resilience, settlement characteristics, city amenities, mixed-use environments, industry decline, industry success, economic development, South Korea
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Publications

Please note that Chapters 2–4 of this dissertation proposal were written as stand-alone papers (see below). Chapter 2 was published in 「The Annals of Regional Science」 in 2022. Chapter 3 is under review after being submitted to 「International Journal of Urban Sciences」 in 2023, and Chapter 4 will be submitted to an academic journal soon.

Chapter 2

Kim, D., Kim, S., & Lee, J. S. (2022). The Rise and Fall of Industrial Clusters: Experience from the Resilient Transformation in South Korea. *The Annals of Regional Science*, 1-23.

Chapter 3

Kim, D., Lee, J. S., & Kim, S. The Role of Amenities in Cities for Employment Growth of Industrial Clusters: Evidence from a Panel VAR Model.

Chapter 4

Kim, D., Lee, J. S., & Kim, S. How Does Mixed-use Development Enhance Industrial Clusters' Competitive Edge? Environmental Satisfaction, Social Capital, and Work Performance.

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CHAPTER 4. HOW DOES MIXED-USE DEVELOPMENT ENHANCE INDUSTRIAL CLUSTERS' COMPETITIVE EDGE? ENVIRONMENTAL SATISFACTION, SOCIAL CAPITAL, AND WORK PERFORMANCE

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Chapter 1. Introduction

1. Research Background and Objectives

In an era of intensifying global competition, industrial clusters have been used to secure national competitiveness effectively. An industrial cluster refers to a geographical agglomeration of firms, institutes, and facilities associated with a specific industry (Porter, 1990). They act as crucial economic pillars for their regions, cities, and nations. Their agglomeration effect benefits firms by providing a business-friendly and cost-effective environment (Marshall, 1890). In addition, they have both forward and backward linkage effects that promote the clusters and their regions to grow. For example, as the automobile industry prospers within a cluster, so do the automobile parts industry and other supporting businesses, such as retail stores and housing for employees and their families. Additionally, labor pools are competently formed because employment opportunities are readily available in industrial clusters, leading to attracting more businesses to the cluster.

However, clusters do not always succeed; in fact, some could fail and deteriorate. When industrial clusters are first built, they are concerned only with growth and the economic benefits they would bring. However, once they decline or are abandoned, they are neglected, resulting in empty factories, a high rate of unemployment, and inefficient land use. Industrial clusters tend to consume a large portion of the government's economic resources and a considerable amount of nation's land, so the decline of a cluster causes significant financial losses.

There has been an extensive discussion of previous studies about the causes of industrial clusters' deterioration (Bartholomae et al., 2017; Drauz, 2014; Krugman, 2009; Menzel and Fornahl, 2009; Qstergaard, 2015; Zucchella, 2006), but they continue to decline. Their inevitable crises come from difficulties in responding to the fourth industrial revolution, changing environmental conditions, the global economic crisis, physical obsolescence, and failing industries. In extreme cases, the economic situation of the areas surrounding the clusters may deteriorate, affecting the entire city (Bukowczyk, 1984). This can reduce income and economic activity in a city, affecting other industries and businesses dependent on the declining clusters.

To accomplish the success of industrial clusters, this thesis prioritizes a multidimensional understanding of their characteristics and status in order to establish an appropriate research solution. To achieve them properly, the thesis comprises five chapters (see Figure 1); Chapters 1 and 5 present the introduction and conclusion of the dissertation, respectively. Chapters 2, 3, and 4 are the body. Each body chapter is a stand-alone paper that focuses on sub-research themes, giving each chapter its own research purpose, methodology, research site, and results. Conducting the research from three different perspectives in each body chapter elucidates the necessary elements that contribute to the success of industrial clusters.

Examining diverse perspectives of industrial clusters is necessary for inclusive decision-making, adaptability, and resilience.

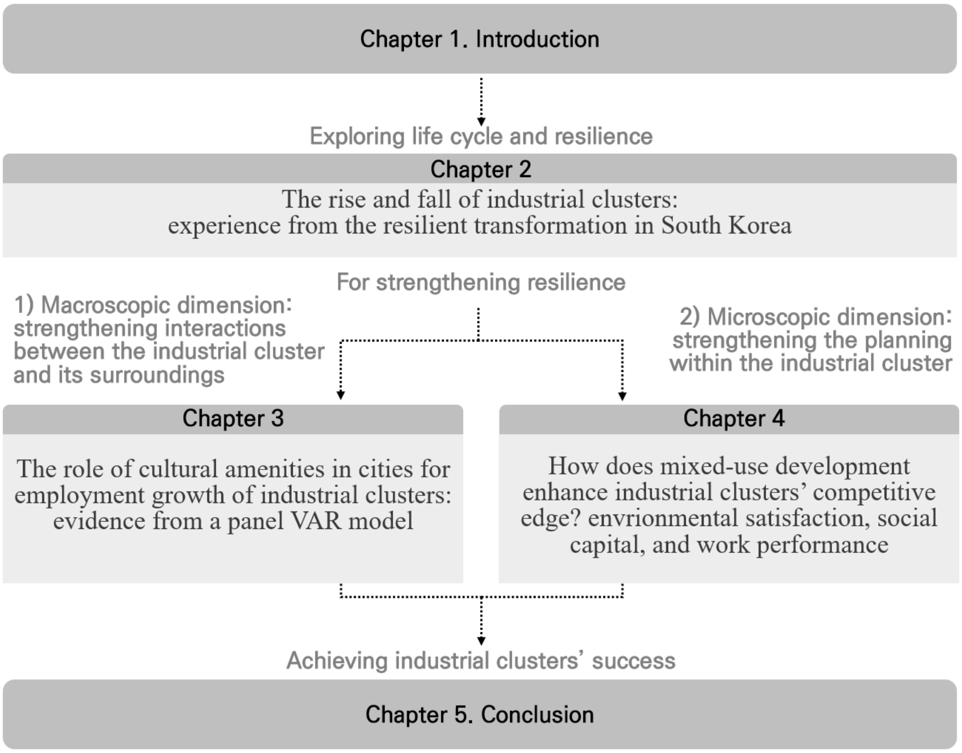


Figure 1 Research Structure Diagram: Multi-Dimensional Approach

In the second chapter, the study "The rise and fall of industrial clusters: experience from the resilient transformation in South Korea" is presented. Understanding the current state and characteristics of industrial clusters allows us to thoroughly examine the problems that industrial clusters face. Examining the life cycle of industrial clusters and their use of resilience allows for a better understanding of the distinguishing traits of clusters by grouping them. Each group's use of resilience is established differently depending on their characteristics. This analysis explains how they build their strengths and achieve success and what factors contribute to their failure. For example, for industrial clusters struggling with issues brought on by factors such as policies or industrial structure, this chapter provides insights into how to strengthen their resilience.

In the third chapter, the study “The role of amenities in cities for employment growth of industrial clusters: evidence from a panel VAR model” is presented as a macroscopic dimension. Industrial clusters do not exist in isolation but are externally influenced by the larger urban context where they are surrounded. An investigation of the impact of city settlement characteristics on employment growth reveals how they interact with each other to achieve the economic growth of industrial clusters. The government has focused heavily on the internal problems of industrial clusters, such as renovating old infrastructure. However, a cluster is considerably affected by the city and its environments; thus, understanding the context in which the city plays its role in the growth of an industrial cluster is critical for fostering the clusters' success.

The fourth chapter presents the study, “How does mixed-use development enhance industrial clusters’ competitive edge? environmental satisfaction, social capital, and work performance” as a microscopic dimension. Analyzing the effects of mixed-use development explains what factors should be considered in future industrial cluster planning for cluster success. The development of mixed-use industrial clusters has become a trend in recent years, with positive expectations for mixed-use land and building developments. However, there is insufficient evidence to support the benefits of mixed-use industrial clusters. As a result, it is necessary to investigate whether this is truly beneficial to the success of clusters. Lastly, the findings and implications are summarized and discussed in the final chapter to suggest a comprehensive approach for successful growth.

2. Definition of Industrial Cluster

The term *industrial cluster* should be clearly defined. An industrial cluster broadly describes most types of industrial agglomeration, including planned or unplanned ones. The most influential study by Porter (1990) and Porter (1998) explained industrial cluster as the geographical proximity of firms, institutes, and facilities associated with a specific industry. Although the concept of industrial cluster may lack clear boundaries, it has become a standard notion (Martin & Sunley, 2003). Therefore, this study adopted this term.

The data primarily used for analysis in this study include the "industrial complex," which is similar to industrial clusters in concept. According to the South Korean Act (Ministry of Land, Infrastructure, and Transport, 2022), these clusters are built in accordance with a comprehensive government plan to collectively construct industrial and support facilities for workers and users. Government-planned industrial clusters exist in many countries, but they are prevalent in developing countries and Asian countries such as China, Singapore, and Taiwan, which are influenced by political location selection and industry support to promote the success of industrial clusters more efficiently (Gwee, 2009; Hu et al., 2005; Liu et al., 2013; Zhong & Tang, 2018). These traits affect industrial policies, corporate management plans, and research institute activities.

Given that the notion of industrial clusters is conceptually extensive, each researcher or country defines related terms differently. Considering the origin of the term, the broadest concept of cluster is one that considers a large unit, such as a city or village, a group of houses, or a military base. These clusters are organized geographically and serve a specific purpose. McCann and Sheppard (2003) used the term, industrial clusters to describe all types of commercial activities grouped together in a space, from an incubator to a big city.

However, simply being gathered does not constitute an industrial cluster. Therefore, some researchers have attempted to define industrial clusters differently. For example, Delgado et al. (2014) proposed defining clusters of related industries through inter-industry linkages, input-output links, and similarities in labor occupations in addition to geographical proximity. This suggests that industrial clusters are determined not only by their geographical proximity, but also by connectivity, such as the network's strength.

Another famous term in the relevant literature is the "industrial districts" by Marshall (1890), which is used to describe the economic productivity of firms that result from their proximity to one another, promoting spatial cluster formation in the long run. This has become famous with the term Marshallian industrial cluster, emphasizing small and medium-sized local firms. As in the example of Italian industrial districts, the small and medium-sized firms network and build exchanges to share benefits, such as exporting goods together. However, this concept does not include the large-scale anchor firms, as Kuchiki (2004) showed that an anchor firm plays an important role in forming industrial clusters in Asia, especially in Japanese manufacturing clusters.

Other terms similar to the industrial cluster are an industrial park or science park, industrial estates, and industrial zone, which all refer to an industry-related concentration, although with minor differences. For example, the terms industrial estate and industrial zone indicate an area designed for the purpose of industrial development. "Industrial Park" is similar to an industrial complex, as it is a large land developed for the use of firms distinguished by its shared infrastructure and proximity to firms (Peddle, 1990). However, this concept tends to be subordinated to an industrial complex because they are usually based around universities (Guy, 1996). They are likely to be planned, whereas an unplanned type of cluster refers to those that have historically and naturally gathered around a location without an initial comprehensive plan.

Other researchers have also attempted to define an industrial cluster with a specific purpose, given the many terms used in the literature to describe the industrial clusters. Here, the terms are categorized primarily based on their industrial characteristics and are classified as in Table 1 with the definition. For example, similar to industrial parks, high-tech parks or science parks refer to clusters of university-based industries. The cultural-creative cluster refers to clusters of creative industries, such as art, music, information technology, and fashion. A business district, factory district, or enterprise zone encompasses broad industries, from manufacturing to corporate concentrations. A financial service cluster refers to the concentration of industries related to finance or services, such as banking or insurance, in the case of a financial service cluster. Lastly, an innovative cluster is a term used to refer to a cluster that applies innovative performance or new technology.

Consequently, industrial clusters are defined differently by countries or researchers due to variations in economic structures, historical development, policy priorities, and cultural factors. Industrial clusters in South Korea are typically planned and organized by the government. These clusters were a crucial part of South Korea's rapid industrialization and economic development, and the government played a central role in fostering industrial growth. It should be noted that these characteristics of the data in South Korea are reflected in the dissertation.

Table 1 Definition of Industrial Clusters

Terms	Definition	Representative Examples
Common Terms		
Cluster, geographic concentration, agglomeration	Geographically close clusters of people or a small group.	City, village, a group of houses, or a military base
Industrial cluster	Geographical proximity of firms, institutes, and facilities associated with a specific industry (Porter, 1990; Porter, 1998).	The broad concept encompassing most of clusters
Industrial district	Small and medium-sized firms, establishing networks and exchanging benefits (Marshall, 1890)	Italian industrial district, such as Tuscany, Italy
Industrial complex	Construction of industry and support facilities in accordance with a comprehensive government plan (Ministry of Land, Infrastructure, and Transport, 2022).	South Korea's industrial complex
Industrial estate, industrial zone	An area designed for the purpose of industrial development.	Jubail industrial city, Saudi Arabia

Specific Terms		
Industrial park, high-tech park, science park, science and technology park	Clusters of scientific and technical industry, centered on universities and research institutes. They support a new company with technical, logistical, administrative, and financial assistance to boost the high-tech industry sector (Guy, 1996; Henriques et al., 2018).	Aston Science Park, UK / Cambridge Science Park, UK / Tsukuba Science City, Japan / Daedok Innopolis, Korea / Hongneung science park, Korea / Zhangjiang high-tech park, China
Cultural-creative cluster, creative cluster	Clusters of creative industries, such as culture, art, music, architecture, software and computer games, advertising, and knowledge (Chapain et al., 2010).	Hollywood film cluster, USA / West End, England / Dundee city for games industry, Scotland / SoHo, USA
Business district, enterprise zone, factory district	Clusters of traditional businesses, offices, manufacturing activity, or factory production that do not necessarily have geographical boundaries, and are often encouraged by tax breaks or government assistance (Erder, 1975; Hall, 1981).	Pearl River Delta, China / The British Enterprise zone, UK / the Sunbelt, USA
Financial service cluster, financial cluster, service cluster	Clusters of finance or service industry, such as banks, investment trusts, pension funding, stock market, and real estates (Pandit & Cook, 2003).	Hongkong / London / Singapore / New York
Innovation cluster, innovation district, innovative cluster	Clusters that are being innovative by achieving innovation, business competitiveness, and economic performance. Innovation in this context refers to the use of new technologies, ideas, or methods to generate revenue, either by creating new products or processes or by improving existing ones (Simmie & Sennett, 1999; Mazur et al., 2016).	Silicon Valley, USA / Biopharmaceuticals cluster, USA / GCE Thames Valley, England

Chapter 2. The Rise and Fall of Industrial Clusters: Experience from the Resilient Transformation in South Korea

1. Introduction

An industrial cluster is defined as a geographical agglomeration of firms, institutes, and facilities associated with a specific industry (Porter, 1990). While a cluster continues to grow, another cluster declines and faces its death. In this way, new industrial clusters are constantly being created around the world. Over the years, China has developed clusters focused on numerous industries, including pharmaceutical and information technology (IT). In recent years, Thailand has steadily developed its industrial facilities, and Indonesia has experienced a rapid increase in the number of clusters under the government's active engagement. Clusters are occasionally created through cooperation between countries, as in the case of clusters in Hanoi resulting from a partnership between South Korea and Vietnam.

Industrial crisis throughout the world is exacerbated by several events, such as the global economic crisis, trade slowdown, Brexit, the US-China trade war, protectionism, and unexpected disasters, including the very recent COVID-19 pandemic. One noteworthy example is the automobile and construction industries in OECD countries stepping into a stage of decline since the global financial crisis of 2007 (Drauz, 2014). Many other clusters have faced a decline by not being able to transform from traditional manufacturing to innovation-oriented, high-tech industries as well as modern business-oriented services (Bartholomae et al., 2017). With the acceleration of high-tech innovation, structural change is becoming essential, and the facilities of aged clusters, which are old and narrow, cause other problems as well. In some extreme cases, an industrial cluster could decline even further into an unrecoverable state after facing several crises.

The paths of industrial clusters are affected by crises throughout their lifetime. In the early years of studies on clusters, their life cycles have been described as a standardized form (Pouter & John, 1996; Klink & Langen, 2001; Zucchella, 2006). This standardized form involves an aging process of birth, growth, decline, and regrowth. As this theory prevailed in the late 1900s, the main study areas focused on old clusters in Western countries. The concept of “resilience” was actively used in subsequent studies later on (Menzel & Fornahl, 2009; Martin & Sunley, 2011). From this perspective, the life of an industrial cluster is an evolutionary process rather than a simple and typical form. When facing a crisis, the life of each industrial cluster flows differently and draws dynamic and irregular curves while undergoing decay or regrowth.

Therefore, the life of an industrial cluster is explained better with a notion of resilience because its growth patterns are determined by how they respond to shocks (Martin, 2012). In this context, the current study defines “resilience” as the ability to return to a previous state, to absorb shock, and/or to adapt to shock in a positive way (Martin & Sunley, 2015). The use of resilience prevents not only catastrophic decline but also limitations to sustained growth. The industrial clusters that have a similar life pattern of increase and decrease share common determinants of resilience. Thus, identifying and utilizing these determinants can help an industrial cluster respond flexibly to any crisis.

The purpose of the current study is to more quantitatively understand the life path of the growth and decline of industrial clusters by verifying actual patterns. Also, it is to explain why these patterns were formed by qualitatively analyzing the process of utilizing resilience. It is important to study how resilience works in the lives of clusters because they function as critical economic bases for their regions, cities, and even countries.

The main contribution of this study to the field of the lifecycle of clusters would be proving the theoretical concepts with data of the entire official industrial clusters in South Korea for two decades. Substantial qualitative works on clusters’ lives have already been conducted; however, quantitative studies that can explain the phenomenon remain insufficient. Although previous works have attempted to define life paths by classifying the groups, they have limitations. Most of their cases only dealt with one or two cases, making it difficult to generalize to a theory that can explain all types of clusters. To achieve this purpose, the life paths of clusters were analyzed in the current study based on the actual data and then categorized into groups. The reasons why patterns were formed also were analyzed according to identified groups.

In addition, the perspectives of Asian countries remain a blind spot in the literature as previous studies have mostly focused on Western countries (Hassink, 2017). Even though Asia's industrial clusters have been actively growing, taking up the next leading role in the global economic arena, the previous works have been unable to prove whether industrial clusters in Asia can be explained by Western theories. Among these, South Korea is considered to be a good example as it has successfully achieved rapid growth within a very short period of time, and the key to its success is the growth of its industrial clusters. The industrial clusters in South Korea, being deeply involved in the development process, have driven the country's economic growth from the very beginning. In addition, South Korea has an optimal condition in which to compare the life paths of clusters because it has designated 1,375 industrial clusters to date, which have grown under similar policies over the years.

Therefore, this study analyzed the life paths of industrial clusters in South Korea for 20 years, classified the types according to their growing and declining patterns, and analyzed the patterns that have been applied to each type of cluster.

2. Literature Review

Previous works on this topic have investigated a cluster's life and degree of resilience. The studies about a cluster's life can be seen from two perspectives: life cycle and evolution. From the life cycle perspective, the cluster's life is an aging process. From the view of evolution, the cluster's life dynamically flows as it encounters events and crises.

The life cycle perspective has been used as a basic idea to explain a cluster's life since the 1990s. This view defines a cluster's life as an aging process from birth to death. It generally has four phases, although one or two phases have been described differently in various ways: 1) birth or development, 2) growth, 3) saturation and stagnation, and 4) decline or regrowth (Klink & Langen, 2001; Porter, 1998; Pouter & John, 1996; Zucchella, 2006). However, the life cycle perspective has a limitation in that it examines a cluster's life following the aging timeline so it cannot be used to explain exceptions that do not follow the process.

The idea of industrial clusters evolving through a series of crises dominated the late 2000s (Martin & Sunley 2011; Menzel & Fornahl, 2009). These studies still admitted that clusters could follow the four basic stages of the life cycle, but clusters change their paths dynamically as clusters undergo success and failure through various crises, such as internal and external problems, breakaways of firms, and a lack of competitiveness. Martin and Sunley (2011) explained the process of evolution as having six possible paths: 1) four basic stages of the life cycle and then replacement by a new cluster, 2) constant innovation, 3) stabilization in the particular state, 4) re-orientation of specialism, 5) failure, and 6) disappearance. According to this perspective, resilience helps a cluster overcome a crisis.

The life paths of clusters are profoundly involved with resilience in a way that it shifts paths after running into a crisis. The concept of resilience has received considerable attention from numerous fields of study, individuals, markets, and countries, so the definitions provided differ in each field. A clear explanation of how resilience works in regional economies was found in what is considered representative research in this field, Martin (2012) and Martin and Sunley (2015). This explains how resilience affects firms' potential paths, and it can also be related to clusters' paths. Martin's (2012) work analyzed the ways in which UK cities respond to regional recessions, namely, resistance, recovery, change, and improvement. Martin and Sunley (2015) have argued that regions react differently to a crisis because the conditions of each region are divergent.

Three possible paths are distinguished in this study after running into a crisis. Representative examples were used to indicate the paths more familiarly. The clusters of each type used resilience in their own different ways. The first path is the Malmo-type, which shows a re-leaping pattern. The clusters of this type struggle with a short-term loss after a crisis but regrow in the long run. Martin (2012) explained this type as a positive hysteretic reaction that the regional economy rebounds more than the pre-shock growth rate, which sometimes leads them to initially experience rapid growth. A typical example is Trafford Park in the UK, whose manufacturing industry suffered a decline but experienced regrowth after a long period of time. Sheffield in the UK also suffered a decline of its old city center along with unemployment due to a decline in the steel industry; however, it eventually succeeded in transforming itself into a cultural industrial city.

The second path is the Silicon Valley-type, which is able to maintain a current state. Martin and Sunley (2015) described this type as returning to its pre-shock growth pattern. It does not always bounce back to the previous growth rate, but it certainly shows regrowing patterns. In this type, a cluster returns to its previous state not long after it experiences the shock of a crisis. As it returns to its previous state, it could go two ways: it could neither increase nor decrease, or it could continue to increase if it used to increase before the incident. Most firms that reached a stagnated phase hardly accept new firms into the cluster (Qstergaard, 2015), which prevents them from further growth. However, Silicon Valley, as an example, keeps forming its network with new entries and it allowed them to continuously grow (Kenney, 1999).

The third path is the Detroit-type, which shows a decreasing pattern. If shock is severe enough, the permanent effects on the growth pattern will prolong (Krugman, 2009). Martin and Sunley (2015) found it happening in the long run when it failed to reorganize or restructure its industry. A cluster does not recover and continues to decline, even after some period of time has passed. In extreme cases, a decline in a cluster could lead to a corresponding decline in the region and city where it belongs. Even an industrial cluster that once flourished could end up being this type if it suffers from stagnation. Two major examples are the decline of the Detroit automobile industry in the US, which caused the decline of the entire city (Bukowczyk, 1984), and the downturn experienced by the large-scale maritime industry of Imabari in Japan.

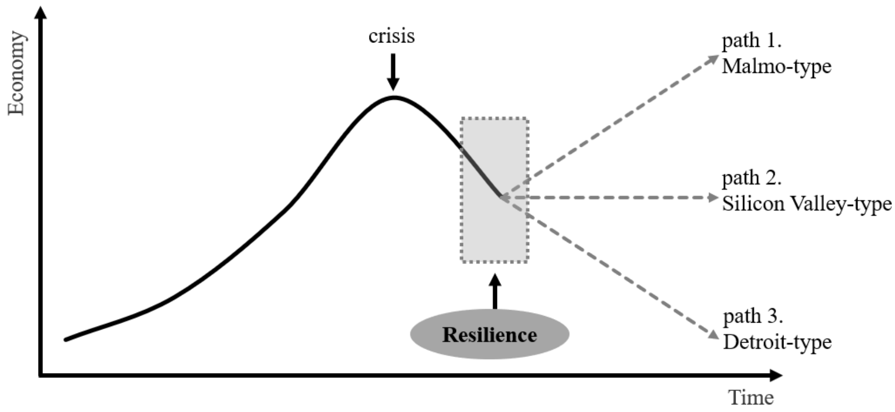


Figure 2 Possible Life Paths

The clusters in each type of path described above share common determinants of resilience, namely, industrial structure, human capital, government policies and support, and location. Table 1 shows the list of resilience examined and extracted from typical factors commonly used in previous lifecycle studies. By properly utilizing these determinants, the clusters can successfully have either the Malmo- or the Silicon Valley-types; otherwise, they will end up having the Detroit-type path.

First, the structure of the industry in a cluster influences its resilience. A cluster could easily restructure to another industry when it has industrial diversification. The dichotomy of economic specialization and diversity has been controversially discussed in the previous literature (Glaeser et al., 1992; Marshall, 1890; Porter, 1990). However, diversification is a substantial condition for growth (Jacobs, 1969), whereas a lack of diversity leads to a cluster's decline (Menzel and Fornahl, 2009). A key element in increasing diversity is embracing new entrants to clusters and accepting new technologies and modes of development (Menzel & Fornahl, 2009; Qstergaard, 2015).

In the Malmo-type path, industrial restructuring is a critical determinant to overcoming a crisis. Clusters' economy can be restored through changes in the industrial structure (Martin & Sunley, 2015). For example, Hong Kong has overcome industrial stagnation by promoting changes in the industrial structures of its clusters (Young, 1992) from manufacturing to the service industry. By taking stagnation as a turning point, the new clusters focused on global trade, logistics, and finance, and in a few years, business services grew successfully on a global scale.

The previous cases of failure having a single industrial structure when the cluster collapses, becomes unstable, and/or causes massive unemployment. The concept of the anchor firm (Kuchiki, 2004) is a large, attractive firm that draws other related firms to its clusters. Then, these clusters grow positively together as they focus on major industries and become dependent on the anchor firm according to the so-called "background linkage effect." However, a crisis could easily reverse this positive effect, which would then have a series of negative effects on the firms in the cluster. The city of Imabari in Japan was famous for having one of the largest maritime industries in the world. However, its shipbuilding industry was intensely stagnated by the Plaza Agreement in 1985, which deteriorated its export competitiveness. Subsequently, stagnation in the manufacturing sector in the 1990s, followed by a collapse of the economic bubble, led to a long-term recession.

Second, the formation of strong human capital strengthens resilience. The number of skilled and qualified employees who remain in a cluster after a crisis determines its resilience (Martin & Sunley, 2015). When clusters struggle with a crisis, the first thing they would do is either reduce employment to recover their financial status or allow employees to leave and look for better jobs. But Boston's successful growth story of reinvention three times through repeated recessions shows human capital takes a considerable role in resilience (Glaeser, 2005). It is critical to maintain talented employees because they are important assets for technology implementation, information collection, and network building.

The determinant of human capital is often used for the Silicon Valley-types of paths. Industrial clusters on a solid growth trend have strong networks among industries, academies, and institutes. To ensure the growth of a cluster, it is important to have an influx of qualified workers looking for jobs or wanting to start their own firms. Information exchange and innovation help strengthen the network, which in turn, enables the clusters to maintain long-term competitiveness (Saxenian, 1990).

For example, the three top bio clusters in the United States, such as Silicon Valley, San Diego, and Boston, have been continuously growing, thanks to their well-established network systems starting from researchers all the way down to production (Yoon, 2007). Research-oriented academic institutions, such as California State University and Harvard University, are cradles of the bio-industry and are known as the driving forces behind its continued industrial development. Meanwhile, Osong Bio Valley in South Korea, built on the combined grounds of research, production, and administration by the government, has experienced continuous growth by actively conducting joint studies for ten years (Yoon, 2007). The bio-industry tends to have a higher connection with basic research institutes, including universities, than other industries, and most of their firms are geographically clustered, with prominent universities collaborating with them.

Third, government support and intervention contribute to a cluster's resilience. Resilience is influenced by government strategies, policies, regulations, and support (Martin & Sunley, 2015). Although government's long-term involvement in the market could result in a negative impact, it legally helps them flourish their industries (Porter, 1990). Government deals with the problems that the market cannot solve on its own, and as a result, the industrial structure changes depending on the government's plans.

Especially, Malmo-type would be difficult to transition to another industry without government support. It is difficult for small enterprises to change the entire industrial structure within their clusters when their main industries face a downturn due to a crisis. It has been shown that government intervention has a substantial impact on industrial growth and structural change (Lee & Jung, 2020), as shown by the example of Singapore and Hong Kong (Wang, 2018). Also, the government of South Korea provided an amicable trading environment with tax subsidies and political support for its export-oriented clusters, which then exported a wide range of products to hugely boost Korea's economy (Kim, 1999). When another problem emerged from the light industry's downturn in South Korea, the government responded by moving on to heavy industries and establishing large clusters.

To alleviate the impacts of crises, governments mitigate regulations, offset export incentives, and expand subsidies for export-oriented clusters (Auty, 1994). Clusters that depend greatly on exports are vulnerable to changes caused by external events and can certainly use their government's support. For instance, most East Asian countries have grown dependent on exports due to scarce resources (Auty, 1994). Their export rate to GDP is so high that some cases even exceed 100%, according to World Bank (2019), while the US, a representative country for high domestic demand, is just around 10%. Indeed, the US can still experience shock from global crises, but the impact of such a shock on the country would be relatively smaller than that on export-oriented countries. On the other hand, East Asian countries have frequently undergone unexpected external events. Korea and Japan, for example, adopted policies on technology subsidies and low-interest rates to foster export-friendly environments (Akkemik, 2008). This helps clusters achieve financial stability when facing a crisis and operate within industry-friendly environments.

Finally, industrial clusters in good locations are more resilient than those in not-so-ideal locations. Martin and Sunley (2015) insist the difference in resilience across regions can contribute to patterns of long-run growth. Location remains an important factor, even though globalization and the new industrial revolution have reduced constraints related to location (Porter, 1999). In the current study, good location means accessibility only in a way that avoids redundancy with other determinants of resilience.

The firms prefer to be located in areas with high accessibility to amenities such as restaurants, nightlife, culture, and sports complexes (Kimeleberg & Williams, 2013). Having good accessibility also means that clusters take advantage of transportation costs because industrial materials are easily conveyed in and out, thanks to the favorable location. The Seoul Digital Industrial Complex (G-valley) also has a substantial advantage by being located in Seoul, thus supporting its consistent growth. In summary, clusters located in metropolitan areas are definitely in high demand among potential firms and workers.

Also, people favor visiting locations with developed infrastructure, such as those with highways, parks, sports facilities, and cultural venues (Florida, 2003). Most people prefer to work in metropolitan areas, where they are guaranteed excellent access to transportation and an attractive environment for business. For example, Paju Book City, an industrial cluster in South Korea, is located far from metropolitan areas, thus imposing a limit on its growth trend due to the inconvenience of commuting there. In comparison, Pangyo Techno Valley, which is located near metropolitan areas, has an optimal condition for attracting human resources, particularly young people (Chung et al., 2017). Thus, it has seen continuous growth in recent years.

The determinants of resilience mentioned above can work individually, but they often work when combined with other determinants. When they exist together, they can produce a more positive effect. For example, although industrial restructuring is an important condition for the Malmo-type path, achieving this would be difficult without government support. Henceforth, this study examines how resilience is involved in a cluster's growth according to each type of path discussed in this section.

Table 2 Determinants of Resilience

Determinants of Resilience	Industrial Structure	Human Capital	Government Policies and Support	Location
Description	A diversified industry has a tendency to be resilient because it has an economy that is easier to back up by restructuring itself into other industries	A strong network built among industry, research, and academia can benefit one another with information change and a qualified labor pool	Government policies that provide support, such as financial benefits and deregulation, increase the resiliency of the clusters	Having a location that favors high accessibility to amenities and infrastructure makes the clusters resilient.
References	Martin & Sunley (2015), Menzel & Fornahl (2009), Porter (1990), Porter (1998), and Qstergaard (2015)			

3. Research Method

This study follows the procedures depicted in Figure 3. The first step is a literature analysis of a cluster's life and its resilience process. The second step is the classification of a cluster's life paths using data from South Korea as a representative case. The classification involved the following steps: data preprocessing, analysis of time-series trends, measurement of similarities between time-series data, the grouping of time-series data, and finally, analysis of the resilience process occurring in each group.

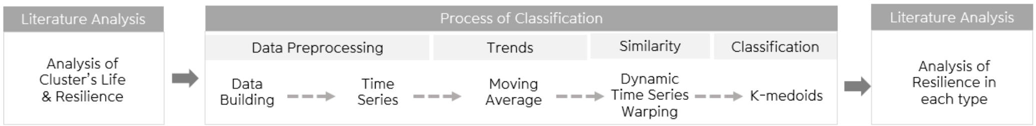


Figure 3 Research Procedure

The representative and quantitative indicators that can explain the growth and decline of industrial clusters with resilience include the number of employees, the total cost of production, and the total cost of export in clusters. These indicators are the evident indexes that demonstrate whether a cluster is growing or declining. These indicators have been affected by clusters since their establishment as they bring economic changes (Kim & Lee, 2012). Most previous quantitative studies have used these indicators as indexes for economic growth. South Korea has steadily accumulated data on these indicators for 20 years; we can use such a dataset to demonstrate growth and decline along with the history of clusters in the country.

Therefore, all three indicators mentioned above were used in this study to analyze patterns of clusters' life paths. The first indicator, the number of employees, explains changes in the cluster populations. A decline in employment implies that the number of job opportunities is decreasing, which would eventually affect the city population where the clusters are located. As stated in a previous study, employment in clusters is related to productivity in a city (Bartholomae et al., 2017). The second indicator, the total cost of production, explains the productivity of clusters by presenting whether the firms in the clusters are currently operating. The last indicator, the total cost of exports, represents vitality, as a decrease in the total cost of exports indicates a decline in clusters. This is especially observable in a country like South Korea, which mostly consists of export-oriented industries.

The changes in time-series data as they increase or decrease determine the degree of growth or decline, respectively. In relation to these, resilience was investigated accordingly in this study. When a decrease was identified, its historical background in the past few years was investigated to determine what had caused the decrease. For example, when the global crisis of 2008 hit every cluster in the world, most clusters' life paths declined, as revealed in the data. Resilience normally works as a response to a crisis, and the figures would be increased if resilience worked out positively.

The data of 1,375 industrial clusters were retrieved from the Korea Industrial Complex Corporation (KICC) as of 2019. It included all previous and current data under the KICC's control, such as all the clusters that are currently not on the KICC's list. Through data refinement, 800 industrial clusters were finally selected. The missing data removed by KICC when it went below the specific number were excluded. Selection Bias might occur since it cannot explain the clusters with very low profits. Thus, time-series data accumulated for almost 20 years from 2001 to 2019 were used in this paper. The data were recorded in the last months of every quarter, namely, March, June, September, and December. The refining process was carried out in three steps. First, the status of the designation was confirmed through the Industrial Land Information Systems, local government websites, and their official news. Second, the changes in names over time were tracked down and corrected. Third, overlapped data were separated, incorrectly combined data were reorganized, and incorrect data were revised. The units that were recorded differently were also unified into employment (persons), production (billion won), and exports (million dollars).

The trend of life paths was calculated using a classic time-series decomposition method, namely, the moving average (MA). The MA is a commonly used calculation for the analysis of stocks and investments when data are too complicated to recognize a trend, mainly due to the periodicity of time-series data. Using this method, a new data point was generated by a series of averages of different subsets of the full data set until a trend in time became reasonably recognizable.

$$\mathrm{MA} = \frac{1}{m}\sum_{j=-k}^{k} y_{t+j} \qquad (1)$$

In the MA equation, shown in Eq. (1) above, k represents a period of time, m is the size of subsets, and y_{t+j} is the value at t+j of the time-series. In brief, subsets of the full dataset are added and divided by the size of subsets, and this process is repeated until all the subsets are averaged. In general, a subset of MA is obtained using odd numbers, such as three, five, and seven, which are more likely symmetrical in data. However, the data of the current study replicated similar patterns in every fourth quarter, and the trend was more smoothly displayed with four; thus, four was used for the size of the subset. The MA makes the original curve smoother so that the trend can be depicted without distortion.

Once the MA was calculated for every life path, dynamic time series warping (DTW) was adopted to measure the similarity between the paths. DTW is an algorithm that measures the distance between two graphs, and the measured distance determines the degree of similarity between them. Since its introduction by Berndt and Clifford (1994), DTW has been used to distinguish human voices by identifying their patterns and shapes. It is also widely used for pattern analysis of time-series. Especially, it is known as the most accurate method of measuring the similarity of time-series data (Wang et al., 2012). DTW is able to overcome the shortcomings of the Euclidean distance method in that Euclidian distance cannot compensate for a distorted or deformed waveform, whereas DTW can find the minimum point in such a form and match it appropriately (Keogh & Pazzani, 1999). The calculation of DTW is conducted using Eq. (2):

$$DTW=|Ai-Bj| + \min (D[i-1, j-1], D[i-1,j], D[i,j-1]) \qquad (2)$$

where Ai and Bj stand for each graph's values, respectively, and D stands for the distance between the two points. Through |Ai-Bj|, a difference between two graphs was measured first, after which the minimum number among the previous values was added.

The DTW algorithm typically cooperates with the k-medoids method, which is a clustering algorithm that classifies graphs. It is an unsupervised machine learning technique that can classify data based on the similarities found. It is similar to the k-means algorithm, which is a more common method for classification. However, k-medoids has an advantage over k-means in that the former can more sensitively recognize outliers of data because it chooses the actual data points as centers to measure similarities, whereas the latter chooses the averaged points as centers. The k-medoids algorithm proceeds in the following order: 1) selecting random data as centers, 2) measuring the distances between the entire datasets and the centers, 3) allocating the data to the closed centers, 4) marking them as a group, 5) calculating the total distance and the so-called total cost, and 6) repeating the steps until the total cost is at a minimum.

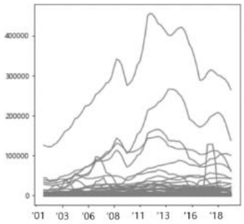
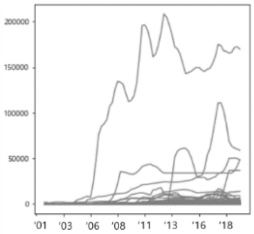
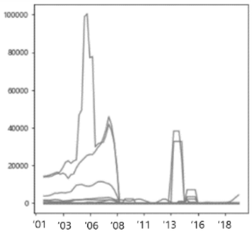
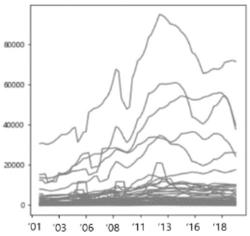
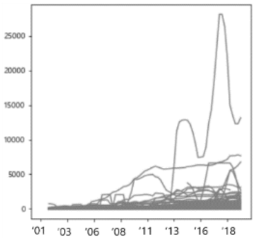
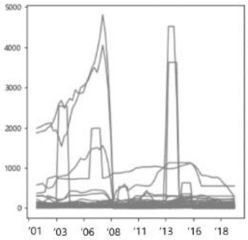
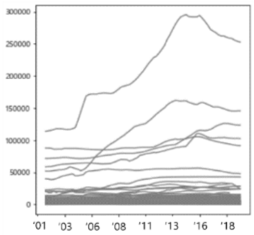
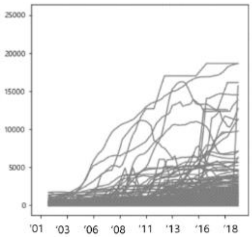
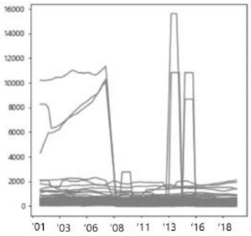
4. Results: Classification

Historically, the South Korean economy has shown an outstanding growth curve among other Asian countries because of its rapid growth in a short period of time. Clusters in South Korea have led its economy from the early stages of its growth, so they are deeply involved in its development. So far, a total of 1,375 clusters have been created and designated under government control, and the same industrial policies, such as tax incentives, have been applied. While these other conditions were controlled, this study classified their life paths and examined the ways in which resilience worked in this context.

As mentioned in the research method section, South Korean industrial clusters were categorized into three groups according to their life paths: Malmo-type, Silicon Valley-type, and Detroit-type. The classification was drawn out by DTW and k-medoids by considering how resilience works in these paths. The analysis was carried out using the Python, which is widely used for data analysis and machine learning. Scikit-learn is the primary library used in the analysis. In a typical machine learning method, 70% of the data is used for training and 30% for testing. Therefore, 70% of the randomly selected data from each section, exports, production, and employment were used for training, and 30% of the data was used for testing. The corresponding accuracy calculated is 93% in exports, 91% in production, and 87% in employment.

In the Malmo-type path, a cluster overcomes a big crisis and grows afterward. It uses two or more determinants of resilience when facing a crisis. In the Silicon Valley-type path, a cluster periodically repeats a cycle of growth, stagnation, and decline, but it maintains a good working state in the long term. This type uses human capital as a form of resilience. Finally, in the Detroit-type path, a cluster gradually shrinks and loses its vitality. Under this path, the cluster does not make good use of the conditions of resilience.

Table 3 Classification

Type	Malmo-type	Silicon Valley-type	Detroit-type
Diagram			
Description	-It overcomes a temporary crisis and rapidly grows afterward. -The global crisis caused stagnation or decline in the last few years.	- It continues to grow since its birth. -It could repeat growth, stagnation, and decline, but it is able to maintain its state in the long term.	-It overcomes some crises in the short term, but it clearly declines in the long term. -The amounts of production and exports, as well as the number of employees, are significantly lower than in other types.
Exports (Unit: Million Dollars)			
Production (Unit: Billion Won)			
Employment (Unit: persons)			
In total	496	125	148
Example	G-valley	INNOPOLIS Daedeok	Gunsan

4.1. The Malmo-type

A cluster that has a Malmo-type path draws a curve that regrows after a decline. As a result of the analysis, the total number of this type is 496, which is 64% of the South Korean industrial clusters. This type even experienced a huge recession like the IMF before 2001, then it rapidly increased by overcoming it as Martin (2012) described initial rapid growth after a shock. They faced several crises afterward, as it is clearly shown in the time-series graphs of the exports amount and the production amount in Table 2, but it had increased steadily until around 2015 when the overall Korean economy took a downturn. The employment rate had a few steady states in the meantime, but it had also been continuously increased until 2015. Exports took a huge role in the economic growth in Korean history, but the growth slowed because the rapid expansion of exports was no longer feasible.

Malmo-type path overcomes a crisis by potentially using all the determinants of resilience, including restructuring, government support, human capital, and location. It fits in the description as Martin and Sunley (2015) mentioned that this type of path overcomes crisis and regrows again by changing its specialism. In the real world, as the graphs show that before they regrow, this type faced turbulence multiple times, and it could not avoid the mega trend of downturn happening in the country in the last five years.

The best example is Malmo, which overcame the crisis and turned over the situation. Malmo is a cluster in Sweden wherein the Kockums shipyard drove its economy. It is located in the North and Baltic Sea, which serves as transportation hubs, leading to the successful development of the local shipping industry back then. However, the so-called “Tears of Malmo” occurred, and the industry was devastated by a loss of its global competitiveness; furthermore, oil shocks occurred in 1973 and 1978. To restore the economy, the Swedish government and Malmo have fostered a knowledge-based and high-tech city centered on IT, media, and biotech since 1994. It has successfully nurtured human resources from Malmo University, supported start-ups through cooperation between the industry and the university, and eventually transformed into an eco-friendly city. Currently, Malmo has attracted highly educated young people to its employment pool (Hsiung, 2014).

Meanwhile, the Guro Industrial Cluster (GIC) shows a Malmo-type path as well. Over the years, it was able to regrow rapidly after a crisis with strong government support and restructuring efforts delivered at the right moment. It had driven the early industrialization and economy of South Korea by focusing on the export-oriented and labor-intensive light industries, such as textiles and clothing, based on the government’s policy since the 1960s.

The GIC has undergone several crises over the years. As the previously dominant light industry declined in the 1970s, the government restructured its main industry into heavy and chemical industries, such as machinery, electronics, and chemistry. However, this economy started going downhill after the peak of exports in 1988 due to the social phenomena of avoiding the 3D (dirty, difficult, and dangerous) industry and rising wages. The IMF financial crisis in 1997 caused the bankruptcy of major companies within the cluster. The cluster’s deterioration also became a huge concern for the government because it would affect the local economy and job market. Thus, the government came up with the “Guro Industrial Cluster Modernization Plan.” This plan drastically conducted deregulation, which allowed research institutes and venture companies, aside from factories, to move into the cluster. Moreover, this plan led to an industrial restructuring into the high technology, fashion design, and knowledge industries. In 2000, the name GIC was changed to “Seoul Digital Industrial Complex”, also known as G-valley.

Another period of change came along as the speculation craze of the “dot-com bubble” in the early 2000s dwindled. As the dot-come bubble ended, IT companies that had been clustered in the Gangnam area, which is the largest IT industrial cluster in Korea, were dismantled, and only the skillful companies survived through it. In fact, this period turned out to be an opportunity for the G-valley. Its merits were considered attractive by many companies, so it became another strong cluster. It had excellent accessibility and a good transport network, which was comparable to those of Gangnam, but at the same time, the price of land and the cost of maintenance were lower. Furthermore, there were only a few restrictions on the expansion of factories or the establishment of corporations even though they were located in Seoul, which had strict regulations at that time. Apartment-type factories were excluded from the regulation policy of total factory number management in the metropolitan area (Ministry of Land, Infrastructure, and Transport, 2004), and it allowed more apartment-type factories to be populated in the G-valley. The new cluster achieved growth by allocating spaces for small and medium-sized companies and by receiving support from the government and other major companies. Moreover, the government supported the move-in of the Knowledge Industry Complex into the cluster and provided tax benefits, deregulation, and low-cost operations. Since then, the G-valley has continued to grow rapidly, especially as it is considered a highly attractive cluster that has drawn great interest from many young people.

Although the trend of its life path seemed to have decreased since 2004, this could be attributed to the separation of the clusters. The KICC used to record the data of the G-valley with those of Juan and Bupyeong under the name of “Korean Export Industrial Complex” in the sections of total exports and production. Therefore, it was not an actual decrease; rather, it kept growing instead. As the Korea Venture Business Association relocated into the G-valley in 2006, it extended its support for venture companies.

Inevitably, the G-valley faced several crises afterward. While the global financial crisis from 2007 to 2008 slowed down the South Korean economy, most clusters survived decreased exports, which led to subsequent reductions in production and employment. Yet, despite the overall economic downturns and declines, employment in the G-valley continued to increase. Between 2012 and 2013, when the economy was unstable due to export stagnation in the manufacturing sector, domestic economic stagnation, and shrinking investment sentiment, the figures related to exports, production, and employment continued to increase. However, the appearance of a competitor, Pangyo Techno Valley, in 2015 brought a big blow to the sustained growth of the G-valley. Even though the G-valley was located in one of the most accessible areas among the industrial clusters in Seoul, Pangyo Techno Valley was more advantageous in many ways. In particular, it is geographically adjacent to Gangnam, Seocho, and Songpa-gu, which are knowledge-based industrial areas; it is also adjacent to Seongnam, Ansan, and Incheon, which have strengths in high-tech manufacturing (Chung et al., 2017). As a result, the G-valley started to decline, losing its competitiveness in terms of cost advantages. Production and employment also showed downward trends due to the trade war dispute in 2018 and the recent downturn in the global manufacturing sector. In response, the G-valley recently devised a countermeasure to attract young people by expanding space and building support facilities, such as rental housing, for start-ups.

The Malmo-type path shares common characteristics. It focused on restructuring an industry facing a crisis under strong government support; it also aimed to attract a young population by using its geographical advantage. This crisis caused a temporary decline, but what makes this type different is that it eventually achieved a regrowth phase after overcoming the crisis.

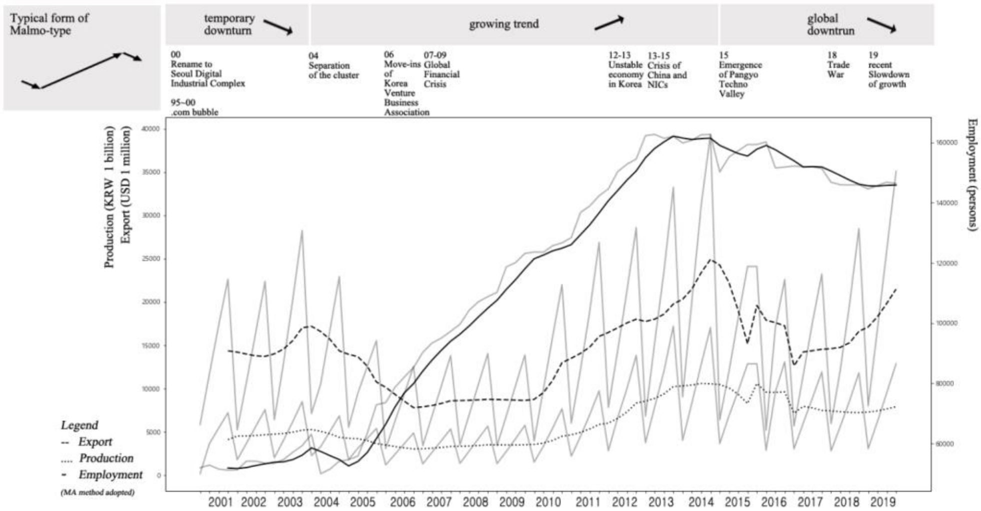


Figure 4 Time-Series Data of the G-valley

4.2. The Silicon Valley-type

The second path is the Silicon Valley-type. As a result of the analysis, the total number of this type is 125, which is 16% of the Korean industrial clusters. As Martin and Sunley (2015) described this type, the graph shows the pattern bounced back to the pre-shock growing rate. It has obviously been challenged by several downturns, such as the global financial crisis, from 2008 to 2009, but the overall trend is upward even after the year of 2015, the economic downturn in South Korea. The employment rate also showed it bounced back to the pre-growth rate after a shock.

This type of path shows a periodical repetition of growth, decline, and stagnation, that is, a cluster overcomes its problems and rises again when faced with a crisis instead of experiencing a decline or collapse. Therefore, frequent crises might occur, but they do not cause rapid changes in the cluster. A cluster may rise and fall repeatedly, but it will not remain in one phase (i.e., either growth or decline). This type of path uses human capital as a major determinant of resilience and establishes strong cooperation among industry markets, academies, and research institutes.

Resilience here is mainly driven by human capital and government support, along with other factors. This type proves that forming strong human capital strengthens resilience, and the representative example of South Korea stayed in a strong growth pattern thanks to the formation of this network. Therefore, the best example is Silicon Valley.

The human capital determinant greatly contributes to Silicon Valley's resilience. As an icon of IT cluster success, Silicon Valley began its journey in 1891. Its resilience was built during the early years when it was developed to attract highly qualified workers to prevent them from spilling onto the Eastern coast. Silicon Valley's continued growth stems from its social network (Saxenian, 1990). In the beginning, it formed a strong bond between the industry and academia through a well-connected system between virtuous workers and Stanford University. This social network became a huge labor pool through frequent employment and turnover in the same field, activated by workers sharing their experiences with one another and openly communicating with new entrant firms. Its resilience was tested when the growth of Japanese semiconductors in the 1980s threatened Silicon Valley. Although some companies failed, the majority managed to upgrade their technology by exchanging information through social networks. Firms jointly invested in essential consulting, network services, and market studies that each individual company could not afford. Despite the recent decline in the US population today, Silicon Valley has contributed to job creation and maintained a continuous inflow of foreign population. It specializes in major industries, such as hardware, software, Internet services, and biotechnology.

In comparison, INNOPOLIS Daedeok in South Korea has become resilient through social networks formed on government-led and university-based research. During its development period from 1974 to 1993, it was the largest R&D cluster in South Korea, with three government agencies, 15 government-funded research institutes, four government investment institutions, and three universities within the cluster (Hwang et al., 2018). Until the end of the 1990s, it was characterized only as a research center because its research results were not entirely commercialized (Lee & Chung, 2014). Through collaboration among the industry, academe, and research institutes, commercialization was allowed by the late 1990s when the "INNOPOLIS Daedeok Management Act" was revised; this was a government-led effort to build business-friendly infrastructure in late 2004 (Hwang et al., 2018). This context explains the explosive increase in production and exports in the cluster since the 2000s.

Since 2005, INNOPOLIS Daedeok has maintained its growing trend without facing a huge shock by expanding space based on the efforts exerted by the national government and the Daejeon Metropolitan City government. Under the "Special Act on the Development of a Special R&D Zone," it became the first dedicated research and development zone of its kind within the country. Guided by the goals of commercializing its research outcomes, creating a business-friendly environment for ventures, building a global environment, and establishing more networks with other regions, its production volume has rapidly increased over the years.

Nevertheless, there was also a temporary decline in the life path of INNOPOLIS. For example, as the cluster's successful exports depended on other countries, it temporarily declined during the global financial crisis of 2007–2008 and the economic crisis of 2015. In contrast, production and employment steadily increased. Employment rates, in particular, increased rapidly from 2010 to 2011. Afterward, its growth continued through the expansion of networks and the diversification of intermediate organizations (Hwang et al., 2018). However, since 2018, its growth rate has shown a decreasing pattern due to the global economic slowdown and a decrease in the value-added rate.

Another cluster that belongs to this type is the Osong Bio Valley, which is dominated by firms engaged in the manufacture of medical materials and pharmaceuticals. Just like INNOPOLIS Daedeok in its early years, it has shown continuous economic growth. The Osong Bio Valley has specialized in the bio-industry since 1997, successfully integrating research, production, and administration through the support and promotion of the government. Its key to success is its strong social network among public institutions, research institutes, and companies. Osong Bio Valley also established a research connection with Chungbok National University's pharmacy college and research center within 600m, as well as other universities such as Korea Advanced Institute of Science and Technology and Chungnam National University, which are 40 to 50km away.

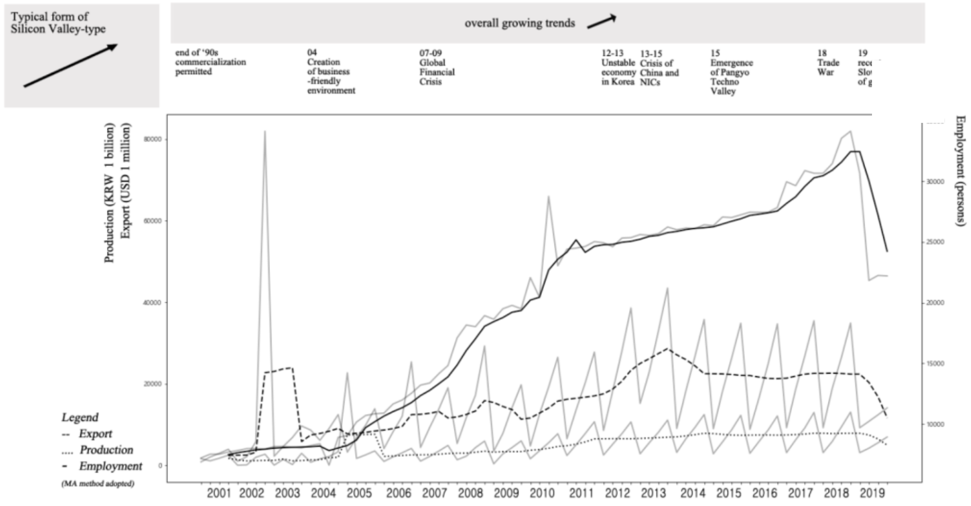


Figure 5 Time-Series Data of INNOPOLIS Daedeok

4.3. The Detroit-type

The third path is the Detroit-type. As a result of the analysis, the total number of this type is 148, which is 19% of the Korean industrial clusters. The severe shock caused a permanent decline (Krugman, 2009). According to the graphs, the industry did not break down or decline at once. It went down a path of deterioration after it went through several harbingers of decline. It might have been able to overcome it during the first time of recession, but it was hard to conquer all the hardships. The amounts of exports and production were upwards until 2008 for most of the cases, and then they dropped to almost zero in a few cases. Several years later, they were able to overcome the obstacle. However, 2015 was a crucial time for every cluster, especially for those who had just overcome the deficit a few years before that, so they declined.

The clusters considered to have the Detroit-type path have a tendency to decline due to their poor utilization of resilience. One common problem with this type of path is the single industrial structure. Focusing on a single industry was an advantage in the early days of cluster formation, but it could occasionally bring fatal consequences, depending on how they dealt with it. This type of path experiences multiple crises, but it is unable to fully recover from each one and the subsequent crises that come their way. Therefore, this kind of cluster continually shrinks, loses its vitality, and eventually declines. In extreme cases, the crisis results in a decline that affects not only the cluster but also the entire city or region. Detroit, a well-known cluster in the US, for example, failed to overcome several crises in the automobile industry and eventually faced its downfall. Detroit was once the largest industrial city in the US in the 1800s and had a great run with Ford, GM, and Chrysler during the 1900s. Since these were large factories, workers rushed to the cluster from all over the region, resulting in a great increase in population and the city's development as well. However, after the industry peaked in 1950, the outflow of the population began. The rising competitiveness of the manufacturing industry in late-comer countries, the emergence of Japanese cars with a cost advantage, and the increased wages of employees in the cluster triggered a crisis in the US automobile industry. In addition, the Detroit riots in 1967 resulted in a massive outflow of the population, which then reduced the tax base and made it increasingly difficult to support urban infrastructure and mitigate the increasing rates of building vacancies. Detroit started from being in an advantageous location surrounded by the Great

Lakes, which was best suited for amphibious transportation. It eventually became difficult for the cluster to overcome the industry's downturn.

Among Korean clusters, this type of path is often found in those clusters that are highly dependent on large companies. Since Korea started focusing on the heavy and chemical industry, it has become the center of the shipbuilding industry in the world. Britain and Japan, which were formidable in the early years of shipbuilding history, faced declines in their industry as a result of various incidents and the loss of their competitive advantages. The Korean government took this opportunity to focus on the shipbuilding industry as a national strategic industry. In the 1970s, clusters in the shipbuilding industry were created, and large corporations were established. Those clusters and corporations included Gunsan (Hyundai Heavy Industries, 1972), Okpo (Daewoo Shipbuilding and Marine Engineering, 1973), Jukdo (Samsung Heavy Industries, 1974), and Jinhae national industrial cluster. During this time, South Korea became a powerhouse in the shipbuilding industry. To date, these companies still represent large corporations in the shipbuilding industry.

The development of the Gunsan national industrial cluster occurred during the 1970s and 1980s as a result of the growth of the automobile and shipbuilding industries. During the process of developing the heavy chemical industry, the economic structure was built with large corporations in which the government's intervention played a central role. The automobile industry of GM (established in 1994) and the Gunsan Shipyard of Hyundai Heavy Industries (established in 2007) have led the regional economy in and out of the cluster. However, the situation worsened with the shutdown of Hyundai Heavy Industries in 2017 and the closure of the GM plant in Gunsan. Subsequently, the companies that depended on these two large companies closed as well. Since then, employment, production, and exports have continuously declined throughout the cluster and the surrounding region, accelerating the decline of the city as a whole. Currently, the Gunsan cluster is all hollowed out. There are vacant commercial and residential buildings and empty streets with “for sale” signs hung everywhere. Although the cluster attempted to shift its primary industry to others, such as the solar energy sector, it had trouble growing in such a short time because this radical structural change required a significant transformation from the previous system and political reliability from the residents.

Meanwhile, the Okpo, Jukdo, and Jinhae clusters in Gyeongnam flourished until 2007, but they followed a similar path as Gunsan. They were unable to overcome the crises they had faced over the years, including the global economic downturn, oil price decrease, and their industry’s downturn, so they continued to stagnate. Samsung Heavy Industries also suffered a deficit due to its accumulated failures, the STX Group was dismantled, and Hyundai Heavy Industries and Daewoo Shipbuilding started cutting back on their operations. Due to the repeated problems caused by the industry’s downturn, production volume decreased, office workers and engineers resigned, and young employees left for other jobs. The population fell more sharply as foreigners’ and workers’ families left along with the workers. This also resulted in a significant drop in enrollees in nearby schools. Furthermore, the industry's related majors, such as naval architecture and oceanography, also showed reduced numbers in 2016, with eight out of 46 students transferring to other majors.

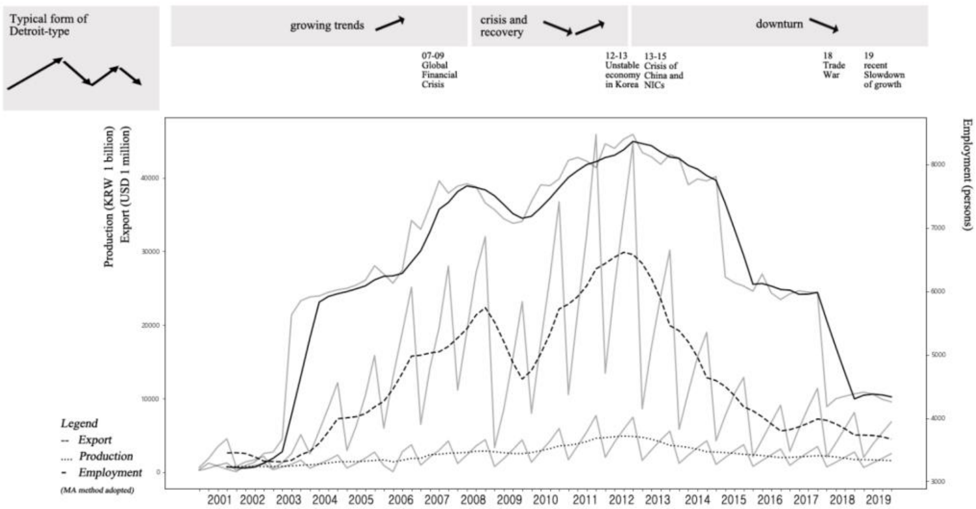


Figure 6 Time-Series Data of Gunsan

5. Conclusion and Limitations

Clusters facing a crisis could have devastating effects on the economic conditions of the regions where they are located. Thus, it is very important to find ways to sustain their success. This research quantitatively classified the life paths of different clusters and analyzed the determinants of resilience that were present when a crisis occurred. By classifying the types of life paths and resilience, we can easily comprehend the trends of clusters' growth and decline.

This classification made it possible to scientifically derive crisis-survivable clusters and to analyze the merits of such clusters. They were classified into three types: Malmo-type, Silicon Valley-type, and Detroit-type. Each type differs considerably from the others in that the Malmo-type and Silicon Valley-type have high resilience, whereas the Detroit-type has low resilience. The types with high resilience made good use of the determinants formed during their lifetime, but the type with low resilience could not make good use of such determinants, making it susceptible to crises.

To promote sustainable development, growth, and operation for clusters experiencing industrial crises, four determinants of resilience must be considered: multi-tiered industrial structure, human capital, government support, and location. When these four determinants come together in harmony, they strengthen a cluster's resilience in the process. Thus, these determinants must be monitored throughout a cluster's lifetime, either by the clusters themselves or by the government. This would help declining clusters get back on track within the short term after experiencing shocks. Otherwise, neglecting even one determinant can lead to a decline, as proven by the cases with the Detroit-type of path.

Each type has a key determinant of resilience that sets it apart from the others. The Malmo-type primarily employs industrial restructuring to overcome a crisis. G-valley, for example, transitioned from old traditional industry to IT and software, allowing them to grow again. The Silicon valley-type mainly relies on human capital. INNOPOLIS Daedeok, for instance, after establishing a strong network, continues to assist one another in remaining strong. The Detroit-type has been severely harmed by poor use of resilience as a single industrial structure. Gunsan, for example, was unable to recover from a series of failures.

This study also has limitations. First, the similarities between the time-series graphs could be measured in a more sophisticated way using a different method. The shapes of the time-series data are very complex, so the DTW method may be unable to capture all the complexities of these patterns. However, the problem with using more sophisticated methods would be classifying the data into more than three groups. If there were many groups, it would be difficult to derive their common characteristics. Therefore, this study grouped them into just three types.

In addition, a future study can conduct quantitative analyses on the correlation between the impacts of a crisis and the determinants of resilience. This analysis will help researchers evaluate which kinds of resilience work in a more supportive way. Also, a future study can compare the differences between Korean and non-Korean industrial clusters in order to identify a path that was distinct from the Anglo-American context.

Additionally, the future study can group the various times-series data types according to the particular policies in effect at the time before moving on to DTW analysis. By doing so, it will be possible to analyze the specific traits and determine how each cluster adopts resilience differently.

Although this research used South Korean data as representative data for classification, the same classification method can be applied to the data of other countries. Through this classification, the necessary or weak determinants of resilience in their clusters can be found. By making up for these shortcomings, continuous growth can be achieved.

Chapter 3. The Role of Amenities in Cities for Employment Growth of Industrial Clusters: Evidence from a Panel VAR Model

1. Introduction

Industrial clusters and cities influence each other (Jacobs, 1969). An industrial cluster is a geographical collection of businesses, institutions, and facilities associated with a particular industry (Porter, 1990). A city refers to the area surrounding the settlement in which an industrial cluster is located. Firms and populations move into the industrial cluster, and their earnings flow back into the city's economy. Some clusters grow as they interact with their cities, while others struggle to grow and instead decline. For instance, Trafford Park transformed Manchester into a world-class industrial city and Silicon Valley has fueled San Francisco's economy. However, a cluster's decline sometimes leads to a decline in its city, such as in Detroit and the automobile industry (Bukowczyk, 1984). What determines success and failure is still up for debate.

Industrial clusters that achieve growth share common characteristics. They have a good settlement environment, which denotes the settlement characteristics that firms and workers prefer. Workers prefer to live in high-amenity areas (Gottlieb, 1995; Green, 2001), and regional growth is affected by the quality of the environment (Power, 1996). Historically, transportation has been a major condition for cluster location because the delivery of agricultural products matters (North, 1955). However, other settlement characteristics are receiving more attention due to improved access to technology, products, and funds. An industrial cluster must have a "want to live" or "willing to work" environment in addition to being accessible. For instance, urban reform programs improved residential conditions to revive the economies of Manchester and Liverpool in the 1920s, when these cities had high unemployment rates and the worst living conditions (Wildman, 2016). However, following the decline of Trafford Park in the 1960s, the quality of workers' lives was improved thanks to the availability of shopping amenities, recreation, and education for resident companies and workers.

2. Research Purpose and Contribution

This study hypothesizes that a more qualified city impacts industrial cluster growth. However, the question remains about how the city interacts with the industrial cluster. For example, when an industrial cluster declines, the government's first response is to focus on the cluster's internal problem, such as by providing financial assistance, upgrading old infrastructure, and widening roads to make goods delivery more convenient. However, understanding the city's role in growth is more important than that of the industrial cluster itself for long-term growth.

The industrial cluster's growth can be understood from how the city plays its role. The city's role in an industrial cluster is critical because it serves employees' needs in a way that the industrial district cannot. Due to the benefits of the agglomeration effect (Marshall, 1890), industrial clusters occupy a sizable portion of a country's land and financial resources. Thus, most cluster locations are outside the cores of cities or are in rural areas. This means they often lack transport options and have insufficient accessibility, over-engineered roads, and fancy facilities like cultural amenities. Industrial clusters primarily accommodate commercial or service facilities, but they hardly accommodate cultural amenities because they are generally beyond bare necessities. Due to their lack of amenities, clusters have trouble attracting workers, primarily those from a younger population; thus, cities should focus on what their industrial clusters lack.

Therefore, this study aims to investigate the interrelationship between clusters and their cities while analyzing which settlement characteristics contribute to cluster growth.

The study makes three contributions. First, it examines the interrelationships between clusters and their city settlement characteristics. How cities' settlement characteristics interact to affect cluster employment growth is not fully understood. The previous studies have shown that high-amenity cities increase regional economies, their focus has been on the effects of the environment, nature, leisure, and transportation (Deller et al., 2008; Gottlieb, 1995; Li et al., 2016; McGranahan, 1999) and the non-physical effects of funding (Löfsten, 2003), environmental policies (Bartik, 1988), and tax benefits (Takatsuka, 2013). To examine the impact more properly about city amenities, this study divides settlement characteristics into four categories, namely commercial stores and service amenities, which relate to a cluster's essential needs, and cultural and educational, which relate to its upscale requirements. Expanding knowledge about settlement characteristics with a focus on city amenities can answer which settlement characteristics must come first in order to prioritize with limited resources.

Second, this study expands on ideas about cultural amenities for industrial clusters. Well-known research by Florida (2003) outlined that a rich supply of culture attracts the creative class, and Frenkel et al. (2013) segmented the creative class to examine its positive impact. However, applying the explanation to the industrial cluster is difficult because the previous research focused on urban areas and the creative class and was criticized for these limitations (Van Heerden & Bontje, 2014). Culture can flourish where vibrant climate, fashion, and cultural festivals are likely to be held (Newman, 2004; He et al., 2018); that is, in places other than industrial districts. Also, cluster members' occupations vary, with blue-collar, technical, and sales workers making up a small portion of the creative class. For example, in Korea, creative groups, such as researchers, represent only around 5.7% of total cluster employment (Park & Jeong, 2013). Because of this specificity, clusters interact with city amenities differently, so understanding the impact of settlement characteristics on cluster employment growth is necessary.

Third, this study uses a panel vector autoregressive (PVAR) methodology to examine how settlement characteristics interact with one another and with employment growth. Understanding which amenities cause another inflow can help regulate which investments are prioritized by industrial cluster growth policy. This enables an understanding of the interrelationship between city amenities while simultaneously considering the impact on employment growth. The study provides a technical contribution by refining the empirical evidence through PVAR analysis. It also compensates for previous studies that did not explain time series changes due to their analysis being at a fixed time point. Previous studies have used a static model, such as a linear regression model (Deller et al., 2008; Li et al., 2016), and controlled endogeneity by employing instrument variables with cross-sectional data (Kim, 2018). However, the nature of their data suggests that time series should also be included in the model because variables such as settlement characteristics and employment have an inherent autocorrelation problem. Thus, a method to assess the impact of settlement characteristics on clusters needs to be refined to support the study's hypothesis.

3. Literature Review

Since quality of life has been attracting increased attention recently (Marcouiller, 1998; Power, 1996), "amenity" is the first element of a settlement's characteristics that workers desire. Amenity is defined in the dictionary as a building or place's desirable or useful features or facilities. Amenities can be cultural or commercial and oriented to leisure, services, transportation facilities, or natural environments. Workers consider not only the quality of the company they will join but also the city in which they will live. Because of this, cities play a crucial role in industrial clusters.

The relationship between a cluster and its city begins as the cluster is formed. The city benefits from the influx of businesses into the cluster, population growth, and Marshall's (1890) agglomeration effect. The income generated by the cluster is reinvested in the regional economy (Jacobs, 1969). The job opportunities provided by the cluster help the community grow, and the city rewards this by offering tax breaks, infrastructure construction, and security (Porter, 1995). As the cluster grows, its city will increase public spending. High investment in infrastructure improves quality of life elements, such as health, safety, economic freedom, and leisure (Barkley & Henry, 2005). An advanced industrial structure improves life expectancy, education, and wages (Gryshova et al., 2020). The city's quality will rise because of infrastructure improvements, drawing in more people and businesses. As the population grows and its needs increase, the city will also gain more amenities. The city's amenities and the industrial cluster are connected in a virtuous cycle.

Results from previous research suggest that a variety of amenities have a positive impact. According to these studies, the amenities that can affect population influx or economic growth are as follows: climate, social, geographic, and environmental amenities influence population growth (Ullman, 1954); natural and built amenities, such as parks, a recreation department, and fishing opportunities influence regional growth (Deller et al., 2008); and natural elements such as trees and open spaces, as well as a quiet environment and low crime rates, influence both businesses and residents (Power, 1996). Also, industrial clusters' sale rate is affected by settlement conditions such as residences, transportation, education, childcare, commerce, medical care, parks, welfare, and cultural and sports facilities (Cho, 2017). In sum, to examine these effects, this study classifies types of amenities into four main indexes, which are commerce, culture, service, and education.

Cultural amenities and educational institutes are considered to be among one of the important settlement characteristics. Thus, it is necessary to examine the importance of these amenities for industrial clusters because although some studies have discussed the value of cultural amenities, they have applied it only to creative classes, mainly in urban areas (Florida, 2003; Frenkel et al., 2013), rather than to industrial clusters. Moreover, a good educational environment is said to result in an increase in the employment rate, with Kim (2018) finding that adding a university to a city increases the number of manufacturing workers. Companies in industrial clusters are more connected to universities than they would be in general locations, adding value to sales volume and employment (Löfsten, 2003). However, more research is necessary to determine how other educational environments, such as elementary, middle, and high schools, affect cluster employment, because when workers' families move in as the population increases in clusters, their settlement needs should also be fulfilled.

In addition, amenities impact one another while encouraging job growth, although it has not yet been determined which amenities affect others in raising cluster employment. Some cases in the past have suggested that one amenity might has an impact over others. One example is Food Valley in the Netherlands, which has a long tradition in food production and commodities. A favorable business climate has enhanced Food Valley’s success, with the government and firms promoting cultural and commercial amenities related to their industries, and the cluster attracts workers such as researchers, developers, and marketing people (Crombach, 2008). Another example is Linkoping in Sweden, which has achieved economic success through interactions between its technology industry and university, resulting in the commercial development of computer technology based on academic research (Klofsten & Jones-Evans, 1996). Another example, Mapo in South Korea, shows that other facilities can also be attracted due to the cultural amenities. Mapo had previously been unappreciated but gained popularity in the late 2010s. Because of the artists who had already gathered in the region, cultural amenities became abundant, and this was followed by a rise in commercial districts with distinctive restaurants primarily run by artists (Mo & Kang, 2022).

4. Method

4.1. Research Spatial Scope

This study’s spatial scope is South Korea (Figure 7). Clusters in South Korea have a close relationship with their cities, making them appropriate for analyzing settlement characteristics. According to the definition of the Industrial Sites and Development Act (articles 2–8, 2022), an industrial cluster is designated, developed, and planned land based on a comprehensive blueprint, so the settlement characteristics are often considered during the planning stage. This comprehensive plan will collectively include factories, research and educational institutes, and other businesses to support them, so its purpose implies inducing business inflow in industrially deficient areas by installing high-quality infrastructure. Moreover, Korea is an attractive place in which to live and work. It is well served by subways, trains, and airports, and various economies and clusters have driven regional growth.

Second, data managed by one institution have accumulated over more than ten years based on the same standards. As of 2019, 1375 industrial clusters were managed by the Korea Industrial Complex Corporation (2010–2019), and four main settlement characteristics were monitored by Statistics Korea (2010–2019). Data collection by a single institute is beneficial for methodological analysis, and it avoids errors that could occur if the data were collected from multiple institutions. This large dataset is advantageous because it can be generalized. Besides these data, other exogenous data were collected by the Korea Statistical Information Service (2010–2019) and Seoul Metro (2022).

4.2. Data

This study aimed to determine whether changes in the settlement characteristics of cities affected the economic growth of their clusters from 2010 to 2019. During the data cleansing process for the stability of panel data, clusters with data for ten consecutive years were chosen, and 706 of 1375 industrial clusters were yielded after the data cleansing process. The 1,375 industrial clusters include not only the existing industrial clusters but also those that were designated to develop by the government but did not develop or were canceled. Consequently, some data were removed for primarily two reasons. First, the majority of industrial clusters are currently devoid of businesses because their construction has just begun and move-ins can take several years. Second, some industrial clusters were no longer operational; therefore, data on industrial clusters that had been designated but canceled prior to 2010 were excluded. Each industrial cluster's employment was collectively summed at the city (unit: Si-gun-gu) level. Accordingly, there were 160 cities that have industrial clusters, as summarized in Table 4. Clusters are summed at the city level to arrange for multilevel data. There are 160 cities, so the aggregate of the data is also 160.

The variables used in this study were (a) endogenous variables to examine interrelationships among settlement characteristics and cluster employment and (b) exogenous variables for a one-way causal relationship that must be managed.

The dependent variable was cluster employment, which is an indicator of the economic growth of a cluster. The independent variables were the settlement characteristics indexes, namely cultural, educational, commercial, and service-related. To recapitulate previous research, the settlement conditions of the cities included nearby commercial stores, cultural amenities, educational institutes, medical facilities, housing, transportation, and services, which enable industrial clusters to perform their functions. Industrial clusters impact not only their immediate surroundings but also the entire city to which workers and their families have access to fulfill their basic settlement needs. Therefore, the scope of this study was the Si-Gun-Gu administrative district unit for a total of 160 cities. The variables in Table 4 and Table 5 were chosen based on data collected under uniform conditions over 10 years and variables applicable to South Korea.

Figure 7 Research Area: Cluster Locations and Their Cities (Unit: Si, Gun, Gu)

Table 4 Spatial Data Summary

Type of Data	Total
Number of cities	160
Number of observations	1600
Number of collective clusters at the city level	160
Number of clusters within cities	706
Period (years)	10

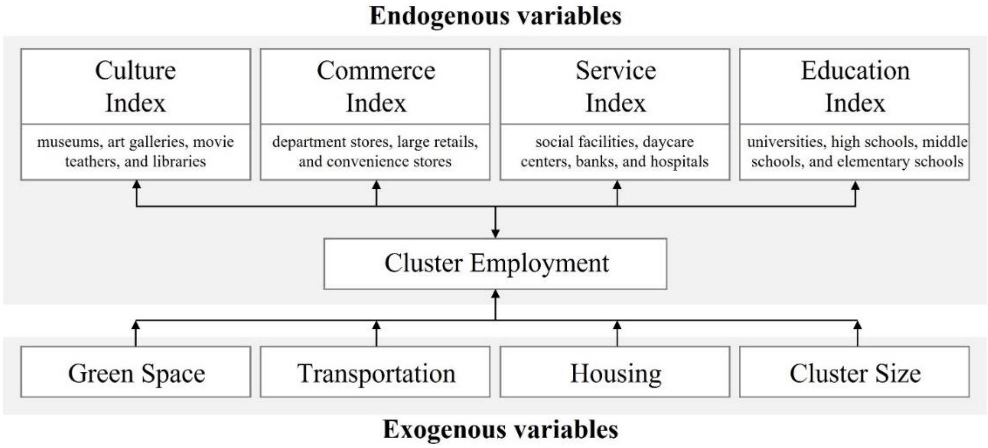


Figure 8 Variable Relationship

Settlement characteristics were chosen based on previous studies (Cho, 2017; Deller et al., 2008; Gottlieb, 1995; Li et al., 2016; Love & Crompton, 1999; McGranahan, 1999). Cultural amenities are facilities and places that people enjoy and include museums (including science centers and planetariums), art galleries, libraries (including national, public, and private libraries), and movie theaters (including both indoor and outdoor activities). Commercial stores, such as convenience stores, department stores, and large retail businesses, provide necessities that people find essential. Large retail businesses include stores that specifically deal with food, clothing, furniture, home appliances, cosmetics, jewelry, and pharmaceuticals, excluding department stores under a single management system. Educational institutes include elementary, middle, and high schools and universities. Service facilities include banks (including domestic banks, such as central and general banks), hospitals (including all types of hospitals, such as internal medicine, general surgery, dentistry, and clinics), welfare facilities (including social welfare facilities for the general population, the elderly, children, and the disabled), and daycare centers (including childcare centers).

Table 5 Descriptive Statistics for Each Settlement Characteristic (n = 1,600)

Underlying Constructs	Variable	Definition	Mean	(S.D.)	Min.	Max.
Commerce Index	***cv.emp***	Total employment at convenience stores	491.6	609.2	1	3,447
	cv.bus	Total number of convenience stores	131.8	153.1	1	855
	dp.emp	Total employment at department stores	13.45	94.81	0	1,099
	dp.bus	Total number of department stores	0.23	0.67	0	4
	rt.emp	Total employment at large retail stores	221.3	429.4	0	2418
	rt.bus	Total number of large retail stores	2.30	3.17	0	18
Culture Index	***mv.emp***	Total employment at movie theaters	32.59	69.88	0	442
	mv.bus	Total number of movie theaters	1.66	2.05	0	11
	mu.emp	Total employment at museums and art galleries	39.41	63.69	0	514
	mu.bus	Total number of museums and art galleries	5.19	5.80	0	43
	lb.emp	Total employment at libraries	59.96	74.61	1	626
	lb.bus	Total number of libraries	9.71	10.82	1	67
Education Index	***es.emp***	Total employment at elementary schools	1276	1,112	139	6,009
	es.bus	Total number of elementary schools	32.40	19.34	4	112
	ms.emp	Total employment at middle schools	652.4	598.0	69	3,548
	ms.bus	Total number of middle schools	15.46	9.64	3	65
	hs.emp	Total employment at high schools	553.3	579.56	1	3416
	hs.bus	Total number of high schools	8.25	6.57	1	44
	uv.emp	Total employment at universities	595.2	1,244	0	8,550
	uv.bus	Total number of universities	1.80	2.19	0	13

Service Index	**bk.emp**	Total employment at major banks, including central and commercial banks	248.4	374.2	1	2,800
	bk.bus	Total number of major banks, including central and commercial banks	21.53	26.76	1	210
	hp.emp	Total employment at hospitals	1,588	2,073	0	14,580
	hp.bus	Total number of hospitals	14.40	15.78	0	98
	sc.emp	Total employment at social welfare centers, including general, elderly, and child welfare	2,826	2,651	149	16,950
	sc.bus	Total number of social welfare centers	281.2	284.9	13	1,574
	dc.emp	Total employment at child daycare centers	1,251	1,390	32	7,114
	dc.bus	Total number of child daycare centers	175.1	208.5	4	1,021

The settlement characteristics index is the weighted value of each settlement condition. The actual influence can be calculated by weighting the number of employees with the number of businesses. It enables the analysis to consider an industry's number, size, and workforce, which individual settlement conditions do not. The higher the index value, the larger the employment size and number of businesses; a value indicates the opposite. For example, the commerce index, as in Equation A, is the sum of the weighted value of settlement conditions such as convenience stores, department stores, and large retail stores.

Equation A. Settlement Characteristics Index Calculation

$$commerce\ index = \left(\frac{cv.emp^{**}}{\sum cv.emp^{***}} \times cv.bus\right) + \left(\frac{dp.emp}{\sum dp.emp} \times dp.bus\right) + \left(\frac{rt.emp}{\sum rt.emp} \times rt.bus\right) \quad \text{Eq.(A.1)}$$

$$culture\ index = \left(\frac{mv.emp}{\sum mv.emp} \times mv.bus\right) + \left(\frac{ms.emp}{\sum ms.emp} \times mu.bus\right) + \left(\frac{lb.emp}{\sum lb.emp} \times lb.bus\right) \quad \text{Eq.(A.2)}$$

$$education\ index = \left(\frac{es.emp}{\sum es.emp} \times el.bus\right) + \left(\frac{ms.emp}{\sum ms.emp} \times ms.bus\right) + \left(\frac{hs.emp}{\sum hs.emp} \times hs.bus\right) + \left(\frac{uv.emp}{\sum uv.emp} \times uv.bus\right) \quad \text{Eq.(A.3)}$$

$$service\ index = \left(\frac{bk.emp}{\sum bk.emp} \times bk.bus\right) + \left(\frac{hp.emp}{\sum hp.emp} \times hs.bus\right) + \left(\frac{sc.emp}{\sum sc.emp} \times sc.bus\right) + \left(\frac{dc.emp}{\sum dc.emp} \times dc.bus\right) \quad \text{Eq.(A.4)}$$

Note 1: Data of employment in the city and data of employment in clusters do not overlap and exclude each other.
Note 2: Total employment of convenience stores in each city (Si-Gun-Gu) by each year.
Note 3: Total employment of convenience stores in the whole research site by each year.

As exogenous variables, *housing*, *transportation*, and *green space* were used. *housing* includes apartments, which represent Korea's typical housing style. *transportation*, selected in terms of accessibility, includes transportation between cities or metropolitan areas (such as the subway, Gyeonggang Line, Jungang Line, and light rail). *Green space* includes children's parks, neighborhood parks, small/nature parks, and municipal and public parks. An exogenous variable must be controlled because it can influence the dependent variable. If exogenous variables are not controlled, the validity of the research results may suffer. A one-way effect in this study means that cluster employment does not affect the three other variables (*housing*, *transportation*, and *green space*); rather, these variables influence the increase in employment.

Parks, for example, are designated at the urban planning level, so it is difficult to assume that an increase in employment does not increase the number of parks. However, a larger park, which means a better environment, can attract more workers. The same is true for subway stations. The subway layout is considered at the planning level, rather than as an event resulting from an unexpected increase in workers. The same applies to apartments, but one should still be careful because most variables in the real world are endogenous; many workers may lead to an increase in housing demand, and thus more apartments being built. Other exogenous variables, such as industrial cluster size, were controlled.

Table 6 Descriptive Statistics for Model Variables (n = 1,600)

Variable Type	Variable	Definition	Mean	S.D.	Min.	Max.
Endogenous Variables	***eply***	Total employment of industrial clusters is collectively summed at the city level	11,896.90	30,102.06	28	298,196
	lneply	Log transformation of *eply*	7.71	1.86	3.36	12.60
	commerce	Weighted number of commercial stores, including department, large retail, and convenience stores	0.05	0.11	0.00	0.85
	lncommerce	Log transformation of *commerce*	0.04	0.09	0.00	0.62
	culture	Weighted number of cultural amenities, including museums, art galleries, movie theater, and libraries	0.01	0.01	0.00	0.10
	lnculture	Log transformation of *culture*	0.01	0.01	0.00	0.10
	education	Weighted number of educational institutes, including universities and high, middle, and elementary schools.	0.01	0.02	0.00	0.16
	lneducation	Log transformation of *education*	0.01	0.02	0.00	0.15
	service	Weighted number of service facilities, including social facilities, banks, and hospitals	0.15	0.31	0.00	2.40
	lnservice	Log transformation of *service*	0.11	0.20	0.00	1.22
Exogenous Variables	***transportation***	Total number of stations, including subway and light rail	1.39	3.34	0.00	22.00
	lntrans	Log *transportation*	0.40	0.80	0.00	3.14
	house	Total number of apartment households (unit: 10,000 dwellings)	4.05	4.71	0.02	25.38
	lnhouse	Log *house*	1.25	0.85	0.02	3.27
	green space	Total size of parks, including children's, neighborhood, nature, pocket, and municipality parks (unit: 1000 km^2).	2.81	4.69	0.00	26.11
	lngreen	Log transformation of *green space*	0.81	0.95	0.00	3.30
	size_desig	Designated size of the industrial cluster (unit: km^2) in total at the city level	6870.12	18,354.69	54	17,1662
	lnsize	Log transformation of *size_desig*	7.28	1.67	4.00	5.15

4.3. Analysis Method: Panel VAR Model

This study used a PVAR model proposed by Sims (1980) that is an extension of the vector autoregressive (VAR) model that can estimate panel data. The model was constructed to verify the research hypothesis that settlement characteristics affect cluster employment and uses the lag phase as an independent variable to estimate the relationship between variables. Holtz-Eakin et al. (1988) created a panel VAR model by combining VAR and panel data. Unlike a VAR, a PVAR can detect individual effects, and analysis is possible even with short-term data (Zhang & Wang, 2020).

The advantage of a PVAR model is that it can estimate the interrelationships between variables by estimating the impact that a city and a cluster have on one another in both directions over time. It captures the static and dynamic interdependence, estimates the links between variables, incorporates the variance of the shocks and time variants, and explains the cross-sectional dynamic heterogenetics (Canova & Ciccarelli, 2013). Every variable in a PVAR model is treated as endogenous, although this study used exogenous variables to account for the expected influence of other variables. This approach can identify the dynamic response of a change in one variable to an endogenous variable with an impulse–response analysis. It is also possible to analyze the relative contribution of each endogenous variable to the overall change with variance decomposition and a statistical test to determine whether a variable is useful in forecasting another through a Granger causality Wald test. In this study, the PVAR model employs the generalized method of moments (GMM) and uses a Helmert transformation to get rid of the fixed effect terms and guarantee stationarity (Love & Zicchino, 2006). The PVAR model (Abrigo & Love, 2016) is presented in equation B.

Equation B. Panel VAR Model

$$Y_{it} = Y_{it-1} A_1 + Y_{it-2} A_2 + \ldots + Y_{it-p+1} A_{p-1} + Y_{it-p} A_p + X_{it} B + u_i + e_{it}$$

$I \in \{1, 2, \ldots, 160\}$, $t \in \{1, 2, 3, \ldots, 10\}$, *for all* $t>p$,

where Y_{it} is a vector of five dependent variables (*lneply*, *lncommerce*, *lnculture*, *lneducation*, *lnservice*), X_{it} is a vector of exogenous covariates (lntrans, lnhouse, lngreen, lnsize), u_i and e_{it} are vectors of dependent variable–specific panel fixed-effects and idiosyncratic errors (Abrigo & Love, 2016), and A and the B are parameters to be estimated. The subscripts are for city (i), on time (t).

5. Results

5.1. Panel VAR Results

This chapter presents the PVAR estimates, Granger causality, variance decomposition, impulse–response graphs (IRF), and cumulative IRF. The PVAR estimate in Table 6 is designed to analyze the interrelationship between variables at first-year lag. The diagram in Figure 10 is based on the panel VAR–Granger causality Wald test, which examines whether the past values of the independent variable are useful in predicting the dependent variable (Granger, 1969). The IRF graph in Figure 9 demonstrates that the duration and magnitude of an effect on cluster employment last when a unit of any settlement characteristic is increased. The IRF graph was originally designed to observe whether a given variable's impulse responds to shocks in another variable. It depicts the effect of increasing one unit at a single point at a particular time. The gray shades of the IRF graph represent the response standard error and the range of accuracy of the measurement. Also, the cumulative IRF graph shows the cumulative sum of the impulse response. Lastly, the forecast error variance decomposition (FEVD) results in Table 7 show the ratio of variables that account for each variable as it changes over the years.

As a result of the Fisher-type unit root test based on the augmented Dicky–Fuller test, data are stationary, and the model satisfies the stability condition after checking the eigenvalue condition after estimating the parameters of the PVAR model. Lag one was selected from lag-order selection statistics using GMM based on Hansen's J statistic. It also passed the overidentifying restriction test at $p = 0.669$.

The results support those of prior research that culture amenities have a beneficial impact on cluster employment, but the results do not support that the education, commerce, or service indexes impact employment growth. The PVAR estimate in Table 6 indicates that the coefficient of the culture index is statistically significant at $p < 0.05$, while the commerce and service indexes are not. Moreover, the education index is statically significant, but it has a negative relationship, and the impacts of the exogenous variables *housing*, *green space*, and *size_desig* on cluster employment are not statistically significant, at $p < 0.05$.

In contrast to past studies, the results show that the culture index is the sole settlement characteristic that significantly affects the influx of cluster employment. Despite the general perception that the commerce and service indexes are essential for employment growth, the culture index is the largest contributor to increasing cluster employment. According to the FEVD results in Table 7, the *lneply* response variable shows that cluster employment itself accounts for 100% of the total variation in employment in the first year, but the ratio decreases over time. In the tenth year, it eventually lowers to 72%, while the culture index is 7.8%, education index is 17.8%, and commerce and service indexes are 0.2 and 0.02%, respectively. The cumulative IRF shows that the culture index has a positive relationship with employment growth, but the education index has a negative relationship.

The employment rate of 72% indicates that industrial clusters contribute highly to themselves, and the influence of settlement characteristics accounts for the remaining 28%. This indicates that industrial clusters themselves have a large pool, leading to high rates of continuous recruiting by providing benefits such as tax incentives and government support, and each characteristic also contributes the most to its own increase (Table 7). Despite its high proportion, of 17.8%, the education index had a negative relationship with employment growth, since this study included elementary, middle, and high schools in addition to universities, which were the focus of most previous studies. With all types of schools considered, there is a negative relationship because overall cluster employment in cities tends to decline when the number of schools increases. From Figure 12, which shows the changes between 2010 and 2019, it can be seen that cities overall are full of educational institutes.

The influence of settlement characteristics accounting for 28% indicates that, in addition to the industrial clusters' own efforts, the other factors that influence employment growth are amenities in this study, since taking 28% as a whole 100%, the culture index is then calculated as 27.8%. The cumulative IRF graph also demonstrates that the culture index is the only characteristic that consistently increases cluster employment. For instance, if a cluster in a city employs 1000 people overall, approximately 300 of them will be impacted by cultural amenities.

It is also proven that cultural amenities are important for cluster employment growth because they affect the influx of other amenities. According to the results of Granger causality and the cumulative IRF, the culture index has a long-term positive impact on the growth of all other indexes, including the commerce, service, and education indexes, as well as culture itself. The maps in Figures 11 and 12 also show that high amenity areas attract high employment growth.

Table 7 PVAR Estimates (n=1,600)

Response of	Response to								
	lneply	*lncommerce*	*lnculture*	*lneducation*	*lnservice*	*lnhouse*	*lntrans*	*lngreen*	*lnsize*
lneply	0.8297***	0.0551	0.7924***	-1.9247**	0.1385	-0.1727*	-0.2386	0.0693	0.0194
	(0.0718)	(0.0987)	(0.1725)	(0.7479)	(0.1229)	(0.0920)	(0.1772)	(0.0784)	(0.7221)
lncommerce	0.1983***	0.5900***	0.2972**	1.5231***	-0.4208***	0.1629***	0.2811**	-0.0861	-0.4165
	(0.0449)	(0.0569)	(0.1420)	(0.4758)	(0.0934)	(0.0592)	(0.1264)	(0.0591)	(0.4855)
lnculture	-0.0010	0.0919**	0.6849***	-0.4548*	0.0778	-0.0638**	-0.0137	0.0379	-0.3315
	(0.0202)	(0.0413)	(0.0753)	(0.2656)	(0.0499)	(0.0292)	(0.0522)	(0.0278)	(0.2572)
lneducation	-0.0091	0.0008	0.0724***	0.5809***	0.0271**	-0.0159**	-0.0267**	-0.0180**	0.0041
	(0.0061)	(0.0094)	(0.0256)	(0.0773)	(0.0126)	(0.0076)	(0.0126)	(0.0083)	(0.0588)
lnservice	0.1580***	0.1320*	-0.7455***	-0.2166	0.5398***	0.0524	0.1302	0.0272	0.0309
	(0.0421)	(0.0730)	(0.1458)	(0.5254)	(0.0857)	(0.0545)	(0.1032)	(0.0486)	(0.4534)

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Note 1: Lag 1 instrument1(1/9)
Note 2: Standard errors in parentheses
Note 3: Test of overidentifying restriction: Hansen's J $chi^2(175) = 166.28$ ($p = 0.669$)

Table 8 Variance Decompositions (Impulse Variable → Response Variable)

Response Variable	Impulse Variable					
	period:year	***lneply***	***lncommerce***	***lnculture***	***lneducation***	***lnservice***
lneply	0	0	0	0	0	0
	1	1	0	0	0	0
	2	0.9469	0.0004	0.0210	0.0296	0.0022
	3	0.8836	0.0034	0.0358	0.0732	0.0041
	4	0.8362	0.0077	0.0426	0.1094	0.0041
	5	0.8043	0.0115	0.0469	0.1338	0.0035
	6	0.7815	0.0141	0.0517	0.1496	0.0030
	7	0.7632	0.0160	0.0577	0.1603	0.0028
	8	0.7471	0.0175	0.0644	0.1682	0.0027
	9	0.7329	0.0189	0.0713	0.1743	0.0027
	10	0.7204	0.0202	0.0778	0.1789	0.0026
lncommerce	0	0	0	0	0	0
	1	0.0239	0.9761	0	0	0
	2	0.0859	0.7611	0.0171	0.0664	0.0696
	3	0.1416	0.5658	0.1174	0.0847	0.0905
	4	0.1575	0.4550	0.2353	0.0716	0.0806

lncommerce	5	0.1616	0.3958	0.3125	0.0609	0.0693
	6	0.1679	0.3633	0.3497	0.0575	0.0616
	7	0.1795	0.3421	0.3644	0.0579	0.0562
	8	0.1950	0.3246	0.3687	0.0595	0.0521
	9	0.2120	0.3086	0.3688	0.0618	0.0488
	10	0.2284	0.2938	0.3670	0.0647	0.0460
lnculture	0	0	0	0	0	0
	1	0.0227	0.0030	0.9743	0	0
	2	0.0163	0.0208	0.9276	0.0251	0.0102
	3	0.0217	0.0506	0.8737	0.0424	0.0116
	4	0.0444	0.0700	0.8267	0.0484	0.0105
	5	0.0779	0.0772	0.7841	0.0499	0.0109
	6	0.1107	0.0785	0.7483	0.0512	0.0113
	7	0.1380	0.0779	0.7189	0.0539	0.0112
	8	0.1604	0.0772	0.6934	0.0582	0.0109
	9	0.1795	0.0767	0.6702	0.0632	0.0104
	10	0.1968	0.0762	0.6487	0.0683	0.0101
lneducation	0	0	0	0	0	0
	1	0.0150	0.0006	0.0166	0.9677	0
	2	0.0109	0.0012	0.0558	0.9249	0.0072
	3	0.0101	0.0050	0.0751	0.8927	0.0170
	4	0.0097	0.0109	0.0806	0.8765	0.0223
	5	0.0105	0.0156	0.0821	0.8681	0.0238
	6	0.0132	0.0184	0.0831	0.8614	0.0238
	7	0.0174	0.0199	0.0847	0.8544	0.0237
	8	0.0219	0.0208	0.0867	0.8471	0.0235
	9	0.0265	0.0214	0.0888	0.8400	0.0233
	10	0.0309	0.0220	0.0908	0.8332	0.0231
lnservice	0	0	0	0	0	0
	1	0.0020	0.0514	0.0041	0	0.9422
	2	0.0311	0.0904	0.1127	0.0029	0.7629
	3	0.1163	0.0856	0.1845	0.0023	0.6112
	4	0.2046	0.0751	0.1894	0.0020	0.5289
	5	0.2674	0.0687	0.1763	0.0038	0.4838
	6	0.3054	0.0644	0.1655	0.0105	0.4542
	7	0.3281	0.0612	0.1580	0.0213	0.4313
	8	0.3435	0.0589	0.1523	0.0329	0.4124
	9	0.3555	0.0572	0.1478	0.0432	0.3963
	10	0.3655	0.0559	0.1444	0.0518	0.3825

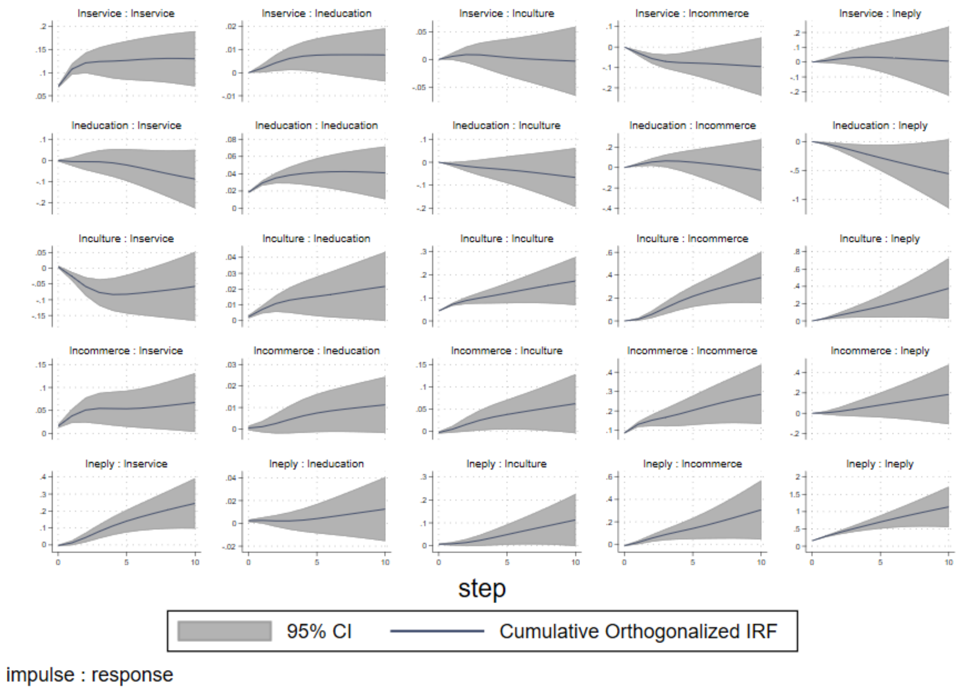


Figure 9 Cumulative Impulse–Response Function

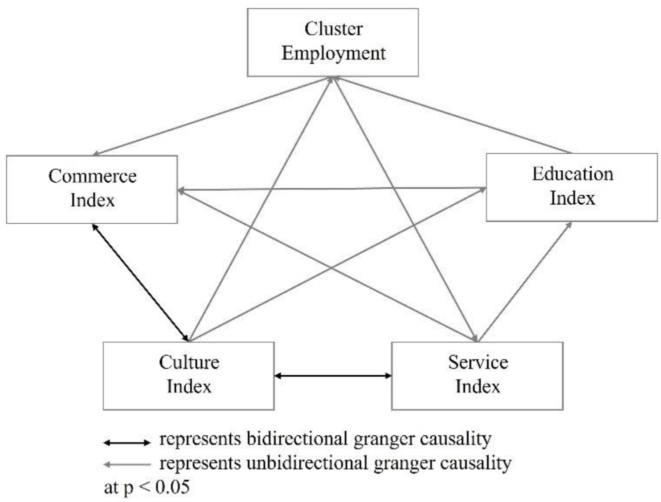


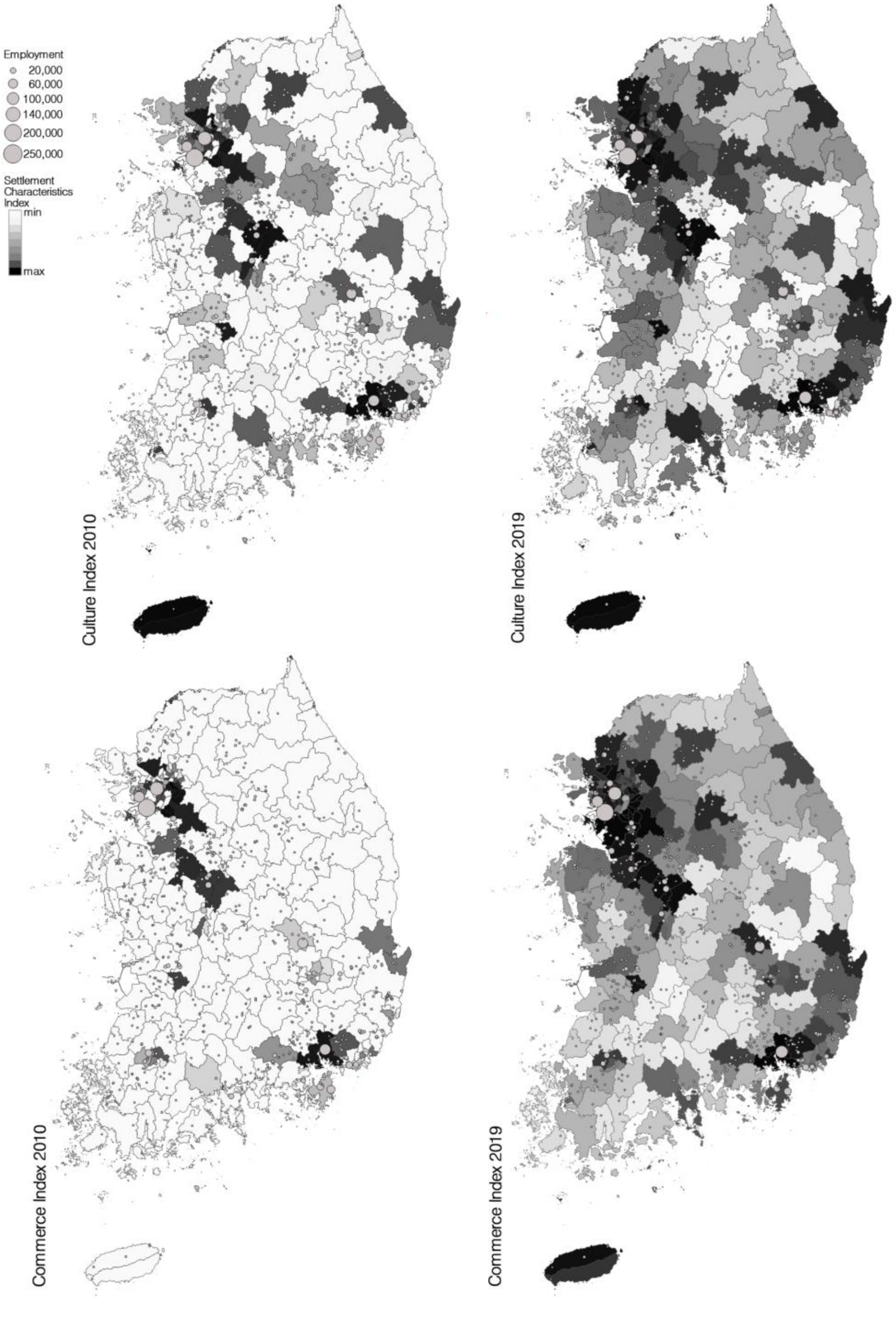
Figure 10 Result of Granger Causality Test

5.2. Changes in Employment and Settlement Characteristics Index

The maps were created using a geographic information system. Figure 11 shows the settlement characteristics index in 2010 and 2019. Also, the maps in Figures 12 and 13 show the changes in each index and employment growth. The darker areas denote a higher index. The circles in Figure 11 show employment in 2010 and 2019. The circles in Figures 12 and 13 depict employment increase, and the triangles represent decrease. The culture, commerce, and education indexes have expanded greatly compared to the service index, which has been high in cities overall since 2010.

Figure 11 demonstrates that metropolitan areas, where employment growth is more likely to occur, have higher culture indexes. Aside from a metropolitan area such as Seoul, which is workers' all-time favorite, cities such as Changwon and Cheongju show instances of the largest cluster employment increasing in a rich cultural amenity area. For example, from Figure 13, it can be seen that Changwon had the highest culture index in 2019, and its employment growth is greater than that of other nearby cities. Changwon also has higher commerce, service, and education indexes than other adjacent cities, resulting in increased employment in seven of Changwon's nine industrial clusters. In contrast, nearby cities such as Gimhae experienced many losses and small gains, and Tongyeong and Sacheon experienced the highest loss among the regions with a low level of cultural amenities. Two industrial clusters in Busan also experienced big losses, since they are in suburban areas where cultural amenities are lacking. The other city, Cheongju, also has an advantage over the adjacent cities due to its high level of amenities and the presence of various administrative institutions and large firms.

The maps also show how amenities affect one another, and the culture index can serve as a starting point. Some cities, such as Gangreung Gyeongju and Yeongwol, experienced a higher increase in the culture index than in other indexes. Gangreung, which is known as a historical and cultural asset, has the highest culture index among the nearby cities. Culture-related events or activities have increased the number of amenities for buying, playing, eating, and seeing. Another city, Gyeongju, is well-known for its historical splendor and has recently regained popularity among the young population due to cultural and commercial influxes, such as in Hwangridan-gil.



Employment
20,000
60,000
100,000
140,000
200,000
250,000
Settlement Characteristics Index
min
max
Culture Index 2010
Culture Index 2019
Commerce Index 2010
Commerce Index 2019

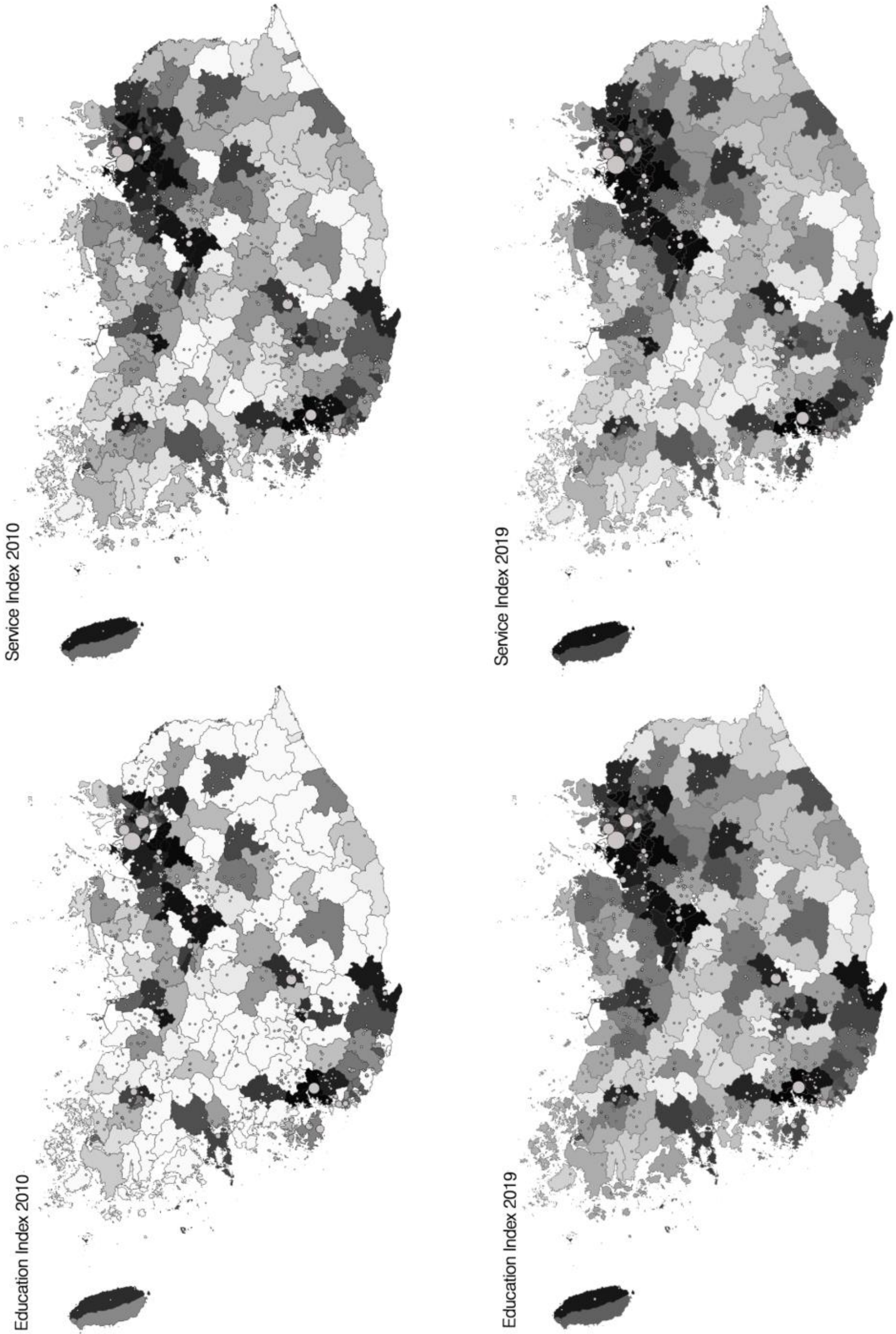


Figure 11 The Settlement Characteristics Index from 2010 to 2019 using a Geographic Information System

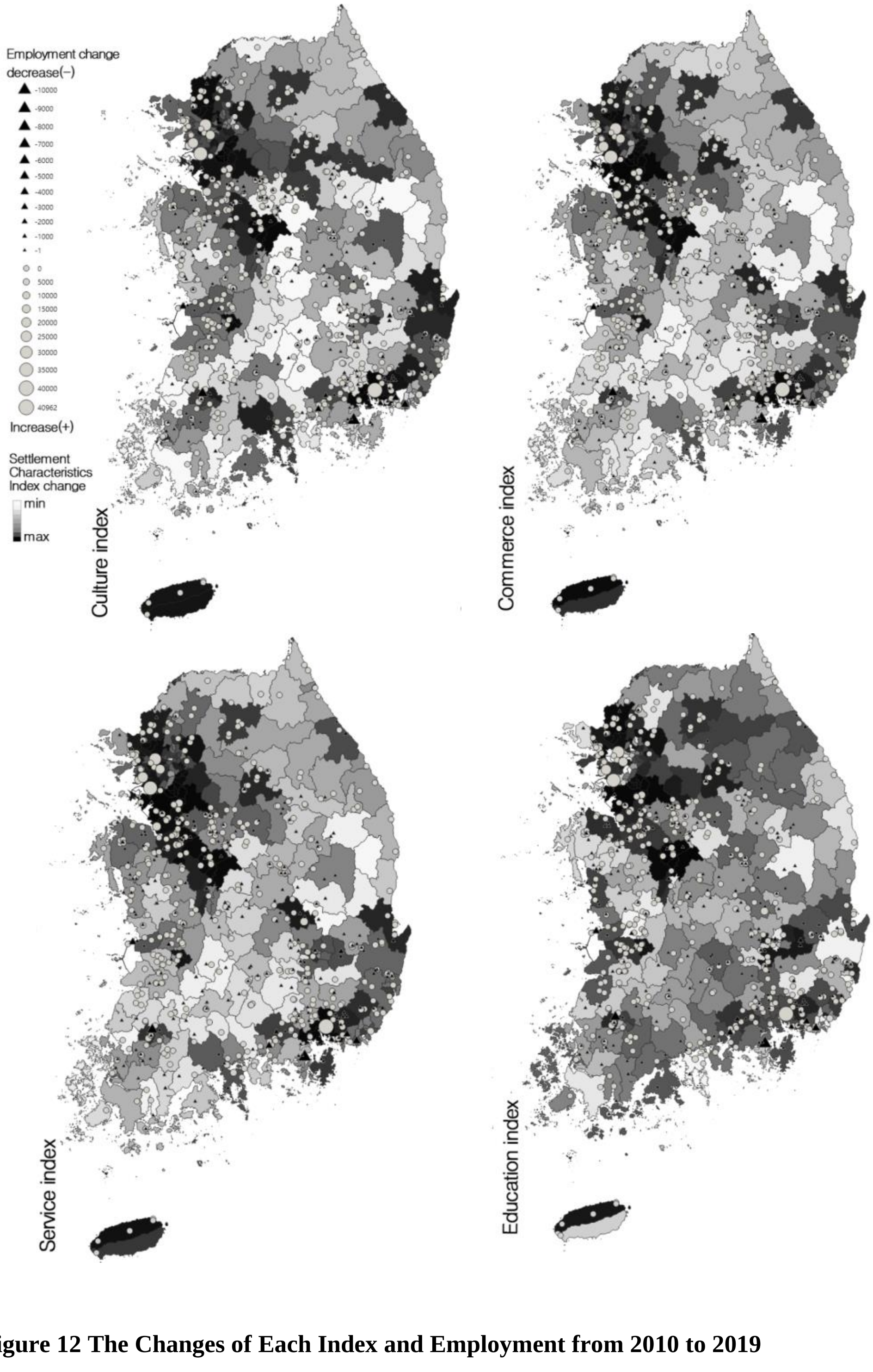


Figure 12 The Changes of Each Index and Employment from 2010 to 2019

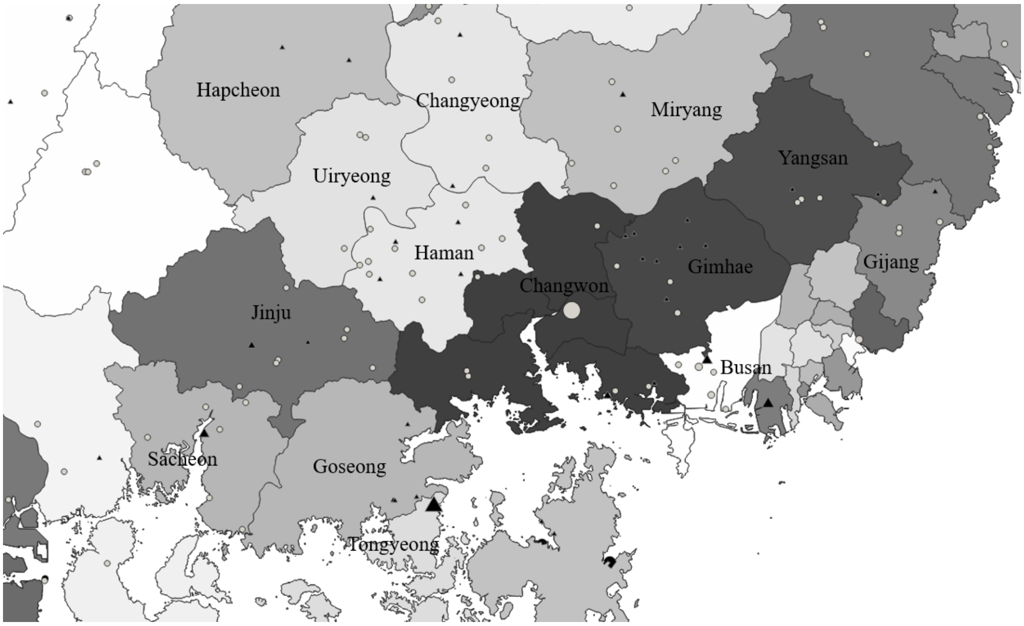


Figure 13 Changwon City and Its Adjacent Cities in the Culture Index Map

6. Discussion and Conclusion

This study investigated the interrelationship between clusters and their cities using PVAR analysis. The results show that culture plays a decisive role in improving cluster employment growth and is more significant than other amenities, including settlement characteristics, housing, nature, or transportation, in the long-term. The results show that cities themselves need to adequately supply cultural amenities in addition to investment in industrial clusters. They also indicate that one cultural amenity has a greater benefit than one education or service facility or commercial store. Even while cultural amenities do not enhance employment directly, they drive the desire for other amenities, strengthening the urban economy, and lead to employment growth in industrial clusters. The culture index attracts other types of amenities to cities, resulting in cities with rich amenities; therefore, it implies that cultural supply investments should be prioritized.

A new perspective that the study can borrow to govern is that cultural amenities are a starting point linked to cluster employment growth. People over 40 comprise nearly half the population of South Korea's industrial clusters, and industrial clusters thus actively seek the influx of a younger population. However, a city with low-quality employment and no cultural amenities for young people is less competitive and attractive. An inflow of cultural amenities is critical to accelerate the growth of the employed population. These factors should be acknowledged when implementing policies, although culture has recently taken a more prominent part than it did in the past.

Having cultural amenities changes a city's atmosphere, and it influences workers' overall satisfaction. Even if workers do not use the cultural amenities directly, culture-related activities take place, and their users keep the city lively and change its atmosphere. Also, improved neighborhoods tend to be qualified with cultural amenities, improving neighborhood quality in return. When a new city or "bed town" is established, essential amenities, such as commercial facilities that can provide food and beverages, are built first. The commerce index in this study indicates necessary elements such as convenience and large retail stores. By contrast, the culture index, which includes amenities such as movie theaters, art galleries, museums, and libraries, only comes into the picture once basic needs are met.

Therefore, the presence of cultural amenities tends to stand for “high-quality” regions. A high-quality region inevitably attracts highly skilled or qualified workers who can afford to live in it. The satisfaction of workers with a neighborhood’s quality will not increase significantly if one or two more banks and convenience stores are added. Conversely, cultural amenities that are not essential but increase quality of life will increase satisfaction.

Since most industrial clusters are located where there are few cultural opportunities, cities with abundant cultural amenities are a major drawing point for employees. Because cities can compensate for amenities that industrial clusters cannot provide because of low business feasibility, providing amenities at the city level is critical. Because most clusters are dull, people only tend to consider them as a workplace and not for recreational activities or residential areas. This leads to a desire to live in different parts of the city. On the other hand, a city with abundant cultural amenities offers a wide range of options for people’s free time, even for cluster employees. For example, an employee living in a rural area would travel to the city center because it has a higher culture index, which means it has a wider range of enjoyable activities. Otherwise, if a city has only one movie theater, which is common in small cities, the user density increases as people congregate in one location. This leads to tickets being bought and moving according to the timetable being difficult. Therefore, rich amenities may allow people to choose their preferred place and lifestyle, and their contentment will definitely rise.

Furthermore, cultural amenities influence the influx of additional facilities to cities, leading to the overall quality being upgraded and resulting in regions with rich amenities. These areas will increase employment, as shown in the results. This positive impact can also be applied in other countries, as evidenced by the examples provided in the previous chapter that showed the impact that amenities have on one another in locations such as Food Valley in the Netherlands (Crombach, 2008), Linkoping in Sweden (Klofsten & Jones-Evans, 1996), and Mapo in South Korea (Mo & Kang, 2022). Austin, Texas, is another example of how abundant cultural amenities attracted people first, followed by businesses and ventures, and they eventually upgraded the city into an ideal place to live (Brooks & Kushner, 2001; Grodach, 2016).

Of course, not every amenity in this study has a positive impact on cluster employment growth, as is the case with the education index, but its negative impact can be explained by the fact that the number of schools in cities overall is fully constructed, even in cities with falling populations. This is because new towns and cities are constantly building schools, while some cities are gradually closing them due to a lack of student enrollment, resulting in an increase in the total number of schools over ten years.

The study has limitations because exogenous variables cannot be completely controlled in real-world situations. For example, in the case of apartments, a new cluster may be built, with companies moving in and jobs created, yet no housing might be constructed. Developers will then rush in, supply homes, and perform development work. The study, nevertheless, addressed this issue as much as possible by controlling them as exogenous variables. Also, the variables that can affect employment growth, such as age, designated size, region (whether they are metropolitan areas), and type of industrial clusters (national, general, urban high-tech, agriculture), were considered before settling on a final model. None of these variables were statistically significant or had significant effects.

Future research needs to go one step further to analyze the effect of settlement characteristics as a whole, in addition to their individual effects. It is also necessary to test the hypothesis with other methodologies and observe longer periods of shocks. Furthermore, future research should consider the effects of city amenities on employment growth in relation to their proximity to each amenity or study areas that are more subdivided, such as at the neighborhood level. Also, young people who are more interested in cultural amenities should be observed more closely, and job occupations should be considered as well.

Chapter 4. How Does Mixed-Use Development Enhance Industrial Clusters' Competitive Edge? Environmental Satisfaction, Social Capital, and Work Performance

1. Introduction and Research Purpose

The construction of industrial clusters with amenities for "live, work, play, learn, and create" (LWPLC) has grown in popularity. LWPLC areas are mixed-use, compact, dense, diverse, connected, and walkable (Malizia et al., 2016). Mixed-use industrial clusters aim to increase their competitiveness by locating non-industrial facilities to support businesses and enhance the working environment. Mixed-use industrial clusters include industrial, residential, commercial, cultural, and institutional buildings. As a representative case, the Poblenou industrial cluster in Barcelona was converted to mixed-use zoning, resulting in a thriving innovation district (Morisson, 2020), and the Trafford Park mixed-use development successfully attracted a young demographic. Further, South Korea has introduced the "mixed site" concept in industrial clusters, which encourages the adoption of mixed-use buildings and land use.

However, prior research on mixed land use has been conducted from both positive (Jacobs, 1961; Jacobs-Crisioni et al., 2014; Rowley, 1996) and negative (Evans, 2014; Lee, 2022; Smith, 2008) perspectives. This indicates that not all aspects of high mixed-use are advantageous. Despite their growing popularity, there are still concerns regarding the efficiency, safety, and performance of mixed-use developments. Therefore, it is necessary to comprehensively examine the effects of mixed-use industrial clusters for insights into treating them as economically viable locations for businesses.

Mixed-use development is a crucial issue in an industrial cluster because it affects the cluster's land-use plan. Land use in an industrial cluster must be managed with intelligence and care as the area under management expands with the development of the cluster (Lambert, 2002). For instance, brownfields, which are deteriorating or abandoned vacant land frequently found in industrial clusters, are ineffective land. The expansion of inefficient land use exacerbates logistical difficulties and vehicular traffic and decreases the landscape's attractiveness, leaving investors with a negative impression (Lambert, 2002).

The competitiveness of an industrial cluster can stem from worker quality, social capital, and environmental conditions. The contribution of this study is the detailed examination of mixed-use industrial clusters in terms of worker performance, social networks, and environmental satisfaction. Multipurpose structure built in industrial clusters have been assumed to be advantageous, but it is difficult to locate a study that demonstrates the performance they can achieve. Prior studies have frequently examined, for instance, the effects of mixed-use at the regional or city level, which increase walking volume or variety.

A pertinent research question is therefore the following: How do mixed-use industrial clusters affect worker productivity and the success of industrial clusters? However, whether mixed-use in industrial clusters creates social networks, influences workability, and affects how individuals interact with their environment remains to be determined. Further, some clusters benefit from separating their location and function from the city, whereas others benefit from converging with a city that can ensure a diverse lifestyle. Therefore, it is necessary to discuss whether mixed-use development has a positive impact on industrial clusters and boosts competitiveness.

The specific research idea is that the impacts of industrial clusters become more positive as their use becomes denser and more complex. The better the surrounding environment, the greater the satisfaction and the more time spent socializing with people, which will increase the worker's sense of belonging and make them want to work for a longer duration. Also, an increase in satisfaction with the surrounding environment will improve worker performance and productivity. Thus, the following hypothesis is advanced: the industrial clusters with more mixed use, would have greater social capital, worker performance, and environmental satisfaction.

Therefore, this study contributes to the literature by 1) assessing the effects of mixed-use industrial clusters, considering the characteristics of individual workers, the type of clusters, and the location; 2) defining the types of mixed-use industrial clusters; and 3) providing policy implications for industrial cluster development, particularly in non-capital areas.

2. Literature Review

2.1. Mixed-Use Industrial Cluster Concepts

Since the Industrial Revolution, concerns about the separation of space and the use of industrial clusters have existed in the Western world. When Trafford Park in England became the first industrial world city in the late 1800s, industrial and residential areas coexisted. However, in the early 1900s, two architects, Le Corbusier and Giedion, advocated and suggested the separation of urban functions for the quality of life (Dzwierzynska & Prokopska, 2017; Lambert, 2002).

As the demand for non-manufacturing facilities increased, mixed-use industrial clusters subsequently emerged. The formation of industrial clusters initially required transportation infrastructure for various industrial materials and additional support facilities for operation (Lambert, 2002). Further, workers and residents within the clusters needed to consume necessities, attracting the building of retail and service stores and, consequently, more workers and customers

(Lambert, 2002). In response to this demand, industrial clusters are increasingly used for non-manufacturing purposes, resulting in the expansion of development and the formation of mixed-use industrial clusters. The current forms of mixed-use industrial clusters become more varied by urban or rural location and by a degree of function separation according to the recent trend of industry diversification.

In this study, a "mixed-use industrial cluster" refers to a multifunctional industrial cluster. Due to the difficulty of defining mixed-use precisely (Evans, 2014), researchers have offered slightly different perspectives. In the literature, both physical and non-physical approaches to the concept of mixed-use are presented. Initially, the most prevalent method was the physical approach. According to Rowley (1996), this includes the physical forms of buildings, blocks, roads, local density, grain, location, tenures, conservation, and incremental change. Nabil and Abd Eldayem (2015) cited numerous methods for measuring this complexity, such as entropy measurement, diversity measurement, the distance between each facility (school, kindergarten, commercial facility), the average street width, and the length of the widest street.

Physically, mixed-use of an industrial cluster entails a complex composition of industries, green spaces, commercial or cultural facilities, and residential facilities. Mixed-use developments can be described as two- or three-dimensional analyses. A two-dimensional description of mixed-use development refers to land use, such as urban planning land-use mix, whereas three-dimensional representations are the form of a building’s mixed-use development (Nabli and Abd Eldayem, 2015).

Heterogeneous uses can be formed within the same building. Given that the land of industrial clusters is limited to similar uses, mixed uses are better defined from a three-dimensional perspective than a two-dimensional one to determine the degree of complexity of an industrial cluster.

From a non-physical approach to mixed-use, the level of complexity should be evaluated alongside human preferences. The presence of a physical environment does not necessarily guarantee the positive effects without considering human. Regarding non-physical factors, Rodenburg and Nijkamp (2004) examined the complexity of space, activity, scale, and time, whereas Sieverts (2003) examined the connection between a city or region and a building. This relationship is affected by people's lifestyles (Evans, 2014), which are influenced differently by each person's characteristics and preferences.

By combining the preceding ideas, the physical concept can be approached by incorporating residential, commercial, cultural, convenience, and research and development facilities, as well as parks, and parking lots. The ratio of these elements can be used to determine the degree of industrial cluster complexity. Further, the non-physical analysis is dependent on the individual's traits and lifestyles.

2.2. Effects of Mixed-Use Industrial Clusters

Positive and negative perspectives on mixed use are controversial and diverse (Nabil and Abd Eldayem, 2015), and most were based on Jacobs's (1961) classic theory that land use diversity stimulates local activities. Mixed use has fundamental advantages in that it increases building density, concentrates activities, reduces energy waste from traffic movement, and promotes diversity (Rowley, 1996). Subsequent studies have examined the effects of mixed-use on cities in a variety of ways, such as the perspective that mixed-use increases housing prices (Wu et al., 2018) and urban activity patterns among residents (Jacobs-Crisioni et al., 2014). Certainly, there are also negative perspectives, such as an increased vacancy rate (Lee, 2022) and contributing to culture-driven gentrification (Evans 2014; Smith, 2008).

Assessing the effect of mixed-use industrial clusters should be approached based on their impacts on the firms and workers that comprise the clusters. The competitiveness of an industrial cluster stems from its attractiveness and rate of sales for businesses because investors are attracted to invest in these developments, factory owners are more inclined to relocate to highly competitive clusters, and workers prefer to work in such pleasant environments. Furthermore, the performance of workers and social capital are the most influential factors in the competitiveness of industrial clusters. Multiple studies have demonstrated that the quality of the labor force and the formation of social capital in industrial clusters have a substantial impact on competitiveness. Therefore, it is critical to determine the extent to which industrial clusters benefit workers.

This study explains the competitiveness in terms of efficiency, networking, and satisfaction rather than the type of primary industry in the cluster or the growth level of the cluster. Therefore, this study attempts to partially reflect the characteristics of companies in industrial clusters. The effects of mixed use were assessed while controlling for the characteristics of the industrial clusters, such as distance from the city center, size, and accessibility to the residence, with a focus on environmental satisfaction, social capital, and work performance.

Environmental Satisfaction

A mixed-use industrial cluster can provide diverse advantages for industrial cluster users, mostly factory owners, entrepreneurs, and laborers. When seeking employment, workers can prioritize two aspects of a company's physical conditions. The first aspect is the location of the company. The company can demonstrate its economic strength by being located in a favorable area, typically located in urban areas with high accessibility and easy commuting or where there is a large labor pool. The second aspect is a well-organized pleasant environment that can be used for short breaks during or after work hours. The availability of a place to take a break affects workers' environmental satisfaction and facilitates additional socialization. As industrial clusters become mixed use, the chance of having a pleasant environment is growing.

Further, people can access a greater variety of lifestyle options when mixed-use development is present. By giving workers and users a variety of options, mixed-use development improves the overall quality of life of those involved. All of these outcomes can be achieved within a neighborhood that is easily accessible on foot—within about 15 minutes of walking distance—and that features a diverse selection of places of employment, services, and entertainment options (Evans, 2014). Despite the differences in workers' preferences and ways of life, the benefits of mixed-use include easily accessible shopping and services, as well as a large number of people congregating in an area and an energetic atmosphere (Evans, 2014). In addition, mixed-use increases the variety of other options available, such as housing styles, and attracts a greater number of employment opportunities (Goodman, 2008). Some individuals hold the opinion that mixed-use developments should be located distinctly from residential areas because they prefer a calm atmosphere (Evans, 2014). However, mixed use can improve people's level of life satisfaction.

Social Capital

Mixed-use industrial clusters can be the foundation for the formation of social capital. Social capital refers to social activities and networks resulting from interpersonal contacts, knowledge, and human resources (Nabil and Abd Eldayem, 2015). Social capital increases cooperation in resolving common problems and diffuses innovation or information through communication. Nabil and Abd Eldayem (2015) examined the relationship between social mix and social capital and concluded that teamwork and cooperation increase as the amount of the mixed-use land increases.

An industrial clusters' social capital can be measured primarily through interactions with coworkers within the clusters, as social capital includes coworkers and work contacts (Stone et al., 2004). Social capital in industrial clusters begins with employment. If an individual belongs to a community, he or she is more likely to be employed, and when that person gets a job, social capital increases not only by virtue of the person's belonging to the community, but also by expanding the labor pool in the community (Stone et al., 2004). These metrics can be evaluated based on how satisfied people are with their coworkers and how much they interact with others. Receiving assistance in changing or finding a job (Stone et al., 2004) can also be a criterion.

The importance of social networks for industrial clusters is a frequent topic of discussion. Socialization within an industrial cluster expands due to frequent meetings with other businesses, the exchange of information, the acceptance of feedback, and marketing activity updates (Felzensztein & Gimmon, 2008). Therefore, it is anticipated that interactions within the clusters will become more active as industrial clusters become more mixed-use.

Perceived Work Performance

Previous studies have demonstrated the workplace's beneficial effect on employee performance (Pawirosumarto et al., 2017; Suprapti et al., 2020.; Sadewo et al., 2021). These studies emphasize that a clean and organized workplace enhances employee performance. Further, the built environment, including density, number of floors, noise, and environmental quality, affects people's mental health (Cooper et al., 2014). This indicator of work performance incorporates the notion of self-assessed perception because it is hard to measure using absolute standards.

Mixed-use industrial clusters would have an effect on performance. According to Zandiatashbar et al. (2019), the productivity of businesses in mixed-use, walkable transit-oriented development, and dense locations increases. Other variables, including environmental satisfaction and social capital, can indirectly influence workers' performance. Mixed-use neighborhoods induce shorter commutes and encourage walking or public transit use (Cervero, 1995), resulting in less traffic congestion or overcrowded parking due to a reduced reliance on automobiles (Cheniki et al., 2019). Less congestion would make commuting comfortable, affecting people's performance. Social capital can also affect performance. For example, Silicon Valley is regarded as a prototypical industrial cluster that expands through social capital (Saxenian, 1990), which influences the work performance of the cluster.

Lifestyle Preference

This study considers lifestyle preferences because mixed-use effects on people are difficult to explain without including human characteristics. The preference for a particular lifestyle is a matter of self-selection, and it is difficult to reflect because each individual possesses a unique trait. Numerous social science studies have focused solely on people's lifestyles (Krizek & Waddell, 2002; Walker & Li, 2007). According to research by Frenkel et al. (2013), workers' decisions regarding where to live are influenced by their preferred lifestyle, such as their culture-oriented or home-oriented activity preferences.

Individual's lifestyle preferences can be classified into three groups. First, introversion and extroversion affect the formation of social networks (Prevedouros, 1992). Extroverts who enjoy interacting with others can achieve high levels of performance in environments that encourage high levels of social interaction. Extroverts without children may be more active. They may prefer to reside near urban areas with a variety of uses, where they can socialize more. However, an introvert may perceive that work productivity increases when social interactions are minimal.

Second, activity frequency, such as the likelihood of going out and visiting many places or staying at home, can influence environmental satisfaction (Krizek & Waddell, 2002). It is possible to determine whether a person who enjoys walking in the park would not use it due to a lack of nearby park facilities or whether the person would not have used it regardless. For example, people who primarily reside at home may not prioritize the availability of various amenities near the workplace. After work, they spend more time in the vicinity of the home, so proximity to amenities at home is more important than the workplace. By contrast, those willing to spend time or pay money to use amenities prefer an area with a variety of amenities near their workplaces, even after work hours. People willing to consume amenities may be content when surrounded by a mixed-use environment. However, they may be dissatisfied if the workplace is not mixed-use and there are few amenities nearby.

Third, distance to work, such as the proximity of the residence to the workplace (Cao & Mokhtarian, 2005; Walker & Li, 2007), can affect performance. Prevedouros (1992) found that personality and income affect the residence location, as lower-income households tend to relocate to high-growth, low-density suburbs, while higher-income households tend to relocate to high-density suburbs. Considering that the proportion of mixed-use properties increases as one moves closer to the city center, where the jobs are mainly located, the preference for mixed-use properties increases as people prefer to live closer to their workplaces.

In addition, the basic characteristics, such as gender, marital status, children, educational background, job type, years of service, and annual salary, are needed to assess personal preferences. People with children are more sensitive to the surrounding environments with regard to education or traffic safety, which affects their choice of workplace. This can lead to lengthening commuting distances or limiting socializing time after work. Further, having children is likely to affect work performance. Work duration is also considered because industrial clusters have a propensity for short-term workers and high job turnover.

3. Methods

3.1. Research Site

The research site is Busan, the second largest city in South Korea. Following Seoul, Busan has the second largest population and a high gross domestic product. There are 30 industrial clusters in Busan, excluding undeveloped or underdeveloped areas after designation as industrial clusters. Specifically, the industrial clusters are divided into 14 study areas, as shown in Figures 14 and 15, based on characteristics of industrial clusters, such as their geographical proximity, designated size, and number of employments. They are influenced by the adjacent area because they are geographically close, especially when their size is small, which increases the likelihood that people will use the buildings in the adjacent area.

Figure 14 Research Site (Administrative Districts: Gun, Gu)

Table 9 Research Site (Name and Code)

Administrative District	Study Area	Industrial Clusters	
		Code	Name
Gijang-gun	A1	a11	Giryong
Gijang-gun		a12	Giryong 2
Gijang-gun		a13	Myungre
Gijang-gun		a14	Eco Jangahn
Gijang-gun		a15	Ori
Gijang-gun	A2	a21	Banryong
Gijang-gun		a22	Busan Advanced Materials
Gijang-gun		a23	Jangan
Gijang-gun	A3	a31	Jung Gwan
Gijang-gun		a32	Junggwan Cori
Gijang-gun	A4	a41	Junggwan Agri
Haeundae-gu	B1	b11	Centum city
Haeundae-gu	B2	b21	Hoedong Seokdae
Sasang-gu	C1	c11	Mora
Sasang-gu	C2	c21	Sasang
Gangseo-gu	D1	d11	Noksan
Gangseo-gu	D2	d21	Shinho
Gangseo-gu	D3	d31	Hwajeon
Gangseo-gu	D4	d41	Busan Newport
Gangseo-gu		d42	Sanggok
Gangseo-gu		d43	Mium
Gangseo-gu		d44	Mium Foreign
Gangseo-gu	D5	d51	Gangseobogo
Gangseo-gu		d52	Busan science
Gangseo-gu		d53	Jisa Foreign
Gangseo-gu		d54	Sungwoo
Gangseo-gu		d55	Jeongju
Gangseo-gu		d56	Jisa 2
Gangseo-gu		d57	Pungsang
Saha-gu	E1	e11	Shinpyung Jangrim

The benefit of selecting Busan is that it has a variety of cases. First, the city center and the outskirts exist, and the outskirts have both an inner circle, close to the city center, and an outer circle. In addition to representative industrial clusters in Busan, there are various forms, from urban convergence types such as regions B and C to urban separation types such as A and D. Second, the types of industries vary by cluster, making it easier to compare the different industrial types. Even the urban convergence type has two different industrial types: manufacturing and high-tech, (Sasang and Centum City, respectively). Third, they are all South Korean types of industrial clusters, such as national, general, urban high-tech, and agricultural. The industries range from primary manufacturing (e.g., leather, textile, and food) and high-level manufacturing (e.g., electrical, electronic devices, and precision manufacturing) to culture-based high-tech industries.

It is also essential to investigate Busan due to its provincial location. Activating local industrial clusters is critical in light of the prevalent contentious issue of provincial cities' demise. Moreover, the impact of the industrial clusters can be assessed without considering the advantages of the capital metropolitan area in terms of transportation and infrastructure. Given that all industrial clusters are located in the same city, errors that may occur when selecting all different areas can be prevented. The city also has the potential to develop more high-tech industries, such as intelligent machinery, due to the city's high concentration of machinery and electronics.

Compared to Busan, metropolitan regions such as Seoul, Gyeonggi, and Incheon are older and utilize more in terms of mixed-use, which could be more advantageous to investigate. However, because the majority of industrial clusters are located adjacent to or mixed into the cities, it is challenging to account for the sole effect of mixed-use. Therefore, the difference in the results for each type may not be statistically significant. Further, even if an industrial cluster is constructed on the outskirt of a city, away from the existing urban area, it can be extended from the current urban area rather than remaining only in outlying areas. In such cases, it may be difficult to measure the effect of the mixed use of a particular industrial cluster because the influence of adjacent cities could be greater than that of the industrial cluster.

3.2. Data

Observed Data: Entropy Measures for Mixed Use

In the majority of studies on mixed use, the entropy index is used to measure mixed-use effect (Brown et al., 2009; Frank & Pivo, 1994; Nabil and Abd Eldayem, 2015). Based on prior research, this study defines mixed use as "the degree to which building uses or parks are mixed." The entropy measures equation is as follows:

$$Mixed\ use\ entropy = -\frac{\sum_{i=1}^{k} p_i \log(p_i)}{\ln(k)}$$

where p_i is a proportion of building area (sq. m) for i, which are building uses, relative to the total area. The total area was determined by combining the total floor area of building uses within each industrial cluster with the green space. The total area did not include roads, rivers, streams, or public open spaces.

k represents the total number of distinct building uses, which was 11. In total, data were collected from 18,491 individual buildings in industrial clusters. According to the classification by Ministry of Land, Infrastructure, and Transport (2023) in South Korea, the main categories are 1) industrial facilities (e.g., factories, factory-related industries, plant, recycle, management, and warehouse), 2) business facilities (e.g., general business, and offices), 3) residential facilities (e.g., detached houses, multi-family houses, multi-family houses, apartments, and dormitories), 4) cultural facilities (e.g., cultural and assembly facilities, religion, and broadcasting), 5) accommodation facilities (e.g., hotels), 6) public services (e.g., public facilities and facilities for the elderly), 7) commercial facilities (e.g., neighborhood facilities), 8) medical facilities, 9) educational facilities, 10) others (e.g., training facilities and parking lots), and 11) green facilities (e.g., parks).

$$
\begin{aligned}
&\mathit{Mixed\ use\ entropy\ in\ an\ industrial\ cluster}\\
&= -\{p_{ind} * \log(p_{ind}) + p_{bus} * \log(p_{bus}) + p_{res} * \log(p_{res}) + p_{cu}\\
&* \log(p_{cul}) + p_{accom} * \log(p_{accom}) + p_{pub} * \log(p_{pub}) + p_{com}\\
&* \log(p_{com}) + p_{med} * \log(p_{med}) + p_{edu} * \log(p_{edu}) + p_{other}\\
&* \log(p_{other}) + p_{green} * \log(p_{green})\}/\ln(11)]
\end{aligned}
$$

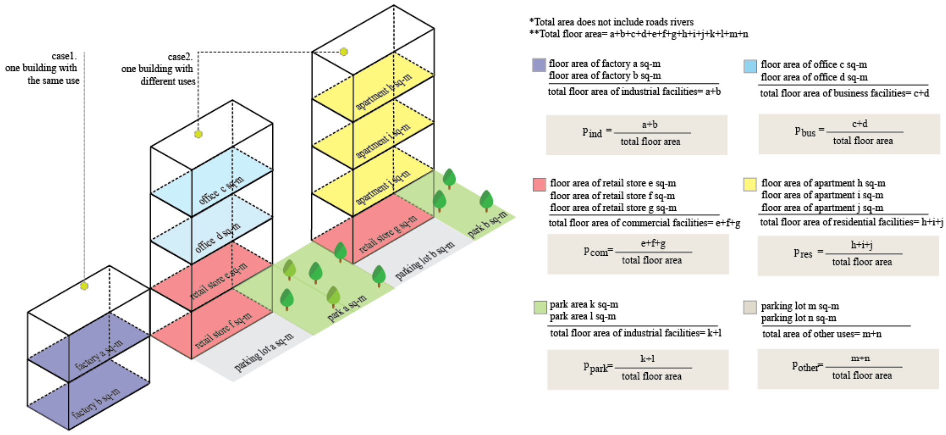


Figure 15 Example of Calculating *pi* for the Entropy Index in an Industrial Cluster

Building location information was structured using a geographic information systems collected from integrated building information from the National Spatial Data Infrastructure Portal. The building used information collected from Government24 and Vos. Land, retrieved in March 2023. Green space information was collected from BDiArchive, and the national city park information standard data were collected from Data.go.kr as of 2020.

Survey

A face-to-face survey was carried out in February 2023. This study was approved by the Institutional Review Board (IRB No. 2302/003-004) of Seoul National University. A total of 1,734 industrial cluster workers in Busan were sampled, and 527 responded, yielding a 30.4% response rate. Questions about the socioeconomic characteristics of the respondents concerned gender, age, marital status, number of children, income, occupation, and years of employment. Questions about the respondents' life preference investigated the characteristics that affect their work performance, environment satisfaction, and social network. To assess the impact of mixed-use developments, questions on performance, environment, and social networks were asked. The number of respondents from each study area is shown in Table 10. The result of the proportional allocation was based on its employment and other factors such as its size or characteristics.

Table 10 Number of Survey Respondents by Study Area

Study Area	Number of Employments	Number of Respondents
A	14,458	100
A1	3,423	15
A2	5,260	17
A3	3,941	17
A4	1,834	51
B	17,970	88
B1	15,597	62
B2	2,373	26
C	18115	79
C1	1,475	25
C2	16,640	54
D	63,385	211
D1	28,337	93
D2	3,381	11
D3	6,390	21
D4	19,674	64
D5	5,603	22
E	14,416	49
E1	14,416	49
In Total (14 Regions)	128,344	527

3.3. Exploratory Factor Analysis and Structural Equation Model

The study employed a structural equation model (SEM). It used the multiple indicators multiple causes (MIMIC) model, a hybrid model consisting of observed variables and latent variables, as its methodology. The observed variable was mixed-use entropy. The latent variables were environmental satisfaction, individual work performance, social capital, and two lifestyle preferences. A latent variable consists of multiple indicators and refers to a variable that can be determined by analyzing unobservable underlying constructs. Each latent variable had a minimum of three questions. These latent variables are measured through the survey. An exploratory factor analysis (EFA) was conducted based on the survey results. EFA simplifies the content of variables by associating multiple questionnaires with a small number of factors. This was followed by SEM, the goal of which was to create a model to present the hypothesized relationships between the various parts of a phenomenon, whether they were observed or theoretical.

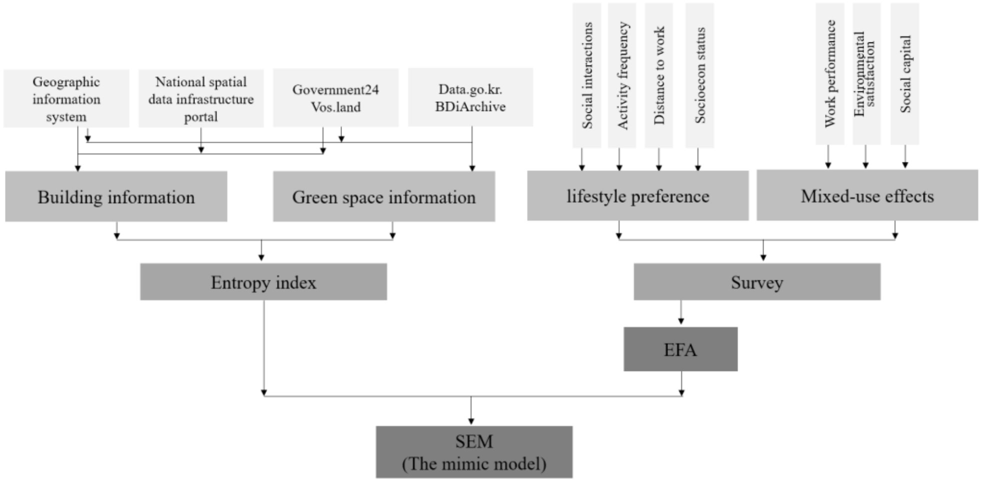


Figure 16 Structure for Analysis Process

4. Results

4.1. Survey

The following are the characteristics of the survey respondents: Notable characteristics were male (54%), married (80%), and having two children (51%). Approximately 80% of respondents had more than one child. Most of the respondents were university graduates (52%), some were high school graduates (20%), and a small portion were junior college graduates (19%). Office workers accounted for the majority of occupations (60%), followed by technical workers (17%) and research workers (6%). In terms of years of service, the most common were 1–3 years (29%), 4–6 years (28%), and 7–9 years (23%), and the opinions of those who had worked for a relatively long time were gathered. The respondents were mostly in their 50s (33%), 40s (27%), and 30s (20%). The most common annual salaries ranged from 4,000 to 6,000 (67%).

Questions regarding the influence of personal propensity and the influence of mixed-use on social capital, environmental satisfaction, and perceived work performance are ranged from 1 to 5. (1: extremely disagree, 2: disagree, 3: moderate, 4: agree, and 5: strongly agree). Overall satisfaction with perceived work performance was high. The average score for all questions ranged from 3.7 to 3.9, with no 1 (extremely dissatisfied) and 4 points being the most common, followed by 3 points. Social capital also received high marks, ranging from 3.3 to 3.7 points. Environmental satisfaction, by contrast, was relatively low (see Table 11).

Table 11 Descriptive Statistics of Latent Variable Indicators (n=527)

Dimensions	Variable	Indicators	Mean	Std. Dev.	Min	Max
Underlying Constructs : Lifestyle Preference						
Social personality	social_work	I enjoy working with people	3.767	0.679	2	5
	social_together	I gain energy and become more active when I'm around other people	3.497	0.721	2	5
	social_friends	I make new friends regularly	3.104	0.810	1	5
	social_outgoing	I prefer interacting with people rather than staying home on my days off	3.632	0.659	2	5
Tendency to use amenities	amen_outtime	I like to spend time outside on the weekends	3.247	0.894	1	5
	amen_shopping	I enjoy shopping at department stores or shopping malls on weekends	2.958	0.948	1	5
	amen_amen	I am willing to pay to use cinemas, art galleries, and museums	2.956	0.971	1	5
Underlying Constructs : Effect of Mixed Use						
Environmental satisfaction	env_amen_distance	I am satisfied with the distance to commercial stores (e.g., restaurants, coffee shops, supermarkets) near my workplace	3.364	0.695	1	5
	env_amen_often	I often visit service facilities (e.g., banks, hospitals, and child care centers) near my workplace	2.968	0.946	1	5
	env_amen_safe	I feel safe and comfortable walking down the street in the industrial cluster where I work.	3.213	0.855	1	5
	env_trans_station	I am satisfied with the interval between trains and the number of public transportation stops near the industrial cluster where I work	3.108	0.788	1	5
Social capital	sns_satis	I am happy with the people I work with	3.689	0.642	2	5
	sns_break	I often talk with people at work during work or breaks	3.577	0.741	1	5
	sns_help	When I look for a job, I ask for help from people around me	3.306	0.822	1	5
Perceived work performance	perform_satis	I am overall satisfied with my job	3.770	0.651	2	5
	perform_ongoing	I want to continue doing the current work	3.918	0.643	2	5
	perform_better	My job is a good place to work	3.791	0.599	2	5
	perform_recomm	I would like to recommend this job to my friends	3.628	0.642	2	5
	perform_perform	I am pleased with how my company has treated me	3.638	0.619	2	5

Table 12 Descriptive Statistics of Variables (n=527)

Variables	Indicators	Mean	Std. Dev.	Min	Max
Entropy	Degree of mixed-use	0.2968	0.2021	0.1110	0.7316
Distance	Distance to the core of the downtown areas	16.277	7.484	7	35
Size	Designated size of regions of industrial clusters (unit: 100,000 sq. m)	39.788	36.493	0.11	101.17
Commute time	Commute time from office to home (0, less than 20min; 1, otherwise)	0.1005	-	0	1
Ratio of factories	Ratio of factories relative to the whole building uses	0.7439	0.2834	0.0760	0.9459
Children	Number of children (0, otherwise; 1,1 or more)	0.6395	-	0	1
Education	Educational background (0, otherwise; 1, university or higher)	4.1917	-	1	6
Occupation	Occupation (0, production worker; 1, otherwise)	3.5731	-	1	6

The descriptive statistics of other variables in Table 12 are about the characteristics of each study area. Entropy for each area and distance to downtown are detailed in Figure 14. The distance from the centroid of the downtown core to each area's centroid was measured because mixed-use development tends to increase near the downtown areas, which must be controlled. The centroid in Busan was determined using geographic information systems according to the 2030 Busan urban masterplan in 2011, which proposed two central districts (Gwangbok and Seomyeon) (Busan Metropolitan City, 2023). They are the oldest original downtown where the city began, and they expanded along with the nearby districts marked in yellow in Figure 14. Busan also has six sub-districts (Haeundae, Dongnae, Deokcheon, Sasang, Hadan, and Gangseo), and four regional centers (Jangan, Gijang, Geumjeong, and Noksan). Further, the size of industrial clusters or commute time, which can impact latent variables, was controlled. Lastly, the ratio of factories was controlled for various types of industrial clusters, ranging from manufacturing to modern industries.

4.2. EFA and SEM Results

The results of EFA were used to determine which indicators were most highly correlated with the latent variables, including L1 (perceived work performance), L2 (social network building), L3 (environmental satisfaction), L4 (social personality), and L5 (tendency to use amenities). This study used Stata for analysis with the vce (cluster) option employed to accommodate and adjust for the intragroup correlation of observations. This study also used a maximum likelihood (ML) estimator.

According to the SEM results, the coefficients of social capital and environmental satisfaction were statistically significant at $p < 0.001$ and sufficiently large. When the entropy value increased by one level, the social capital and the environmental satisfaction both increased by 0.329 and 0.340, respectively. Further, when the social personality increases, perceived work performance and social capital increase by 0.349 at $p < 0.01$ and 0.152 at $p < 0.1$. Also, as personal tendency to use amenities increased, environmental satisfaction increased by 0.174 at $p < 0.1$. By contrast, an increase in the value of entropy was not statistically significant for performance. However, an increase in entropy indirectly affected perceived work performance via social capital, which was increased by environmental satisfaction, by 0.22 at $p < 0.05$, as shown in Table 13.

Therefore, as mixed use in industrial clusters increases, people are more likely to be satisfied with their co-workers, socialize more, and give and receive assistance from one another. In addition, individuals with high sociability and who actively spend time and money on amenities create more social networks. Additionally, shorter commute times influence greater environmental satisfaction and work performance. As the distance from the downtown area is further away, the satisfaction decreases, and as the designated size gets bigger, the social capital and perceived work performance decrease.

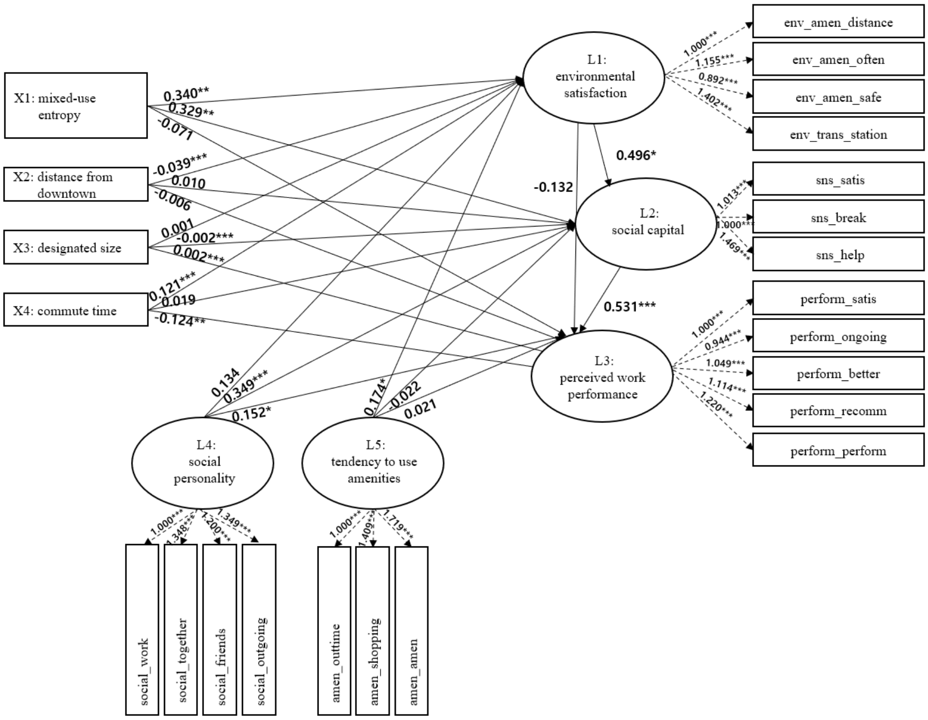


Figure 17 SEM Results (P <0.1 *, P <0.05**, p <0.01***)

Table 13 Direct, Indirect, and Total Effects

Effects		Direct Effects			Indirect Effects			Total Effects		
on	of	coef.	std.Err	p-value	coef.	std.Err	p-value	coef.	std.Err	p-value
L1. environmental satisfaction	Entropy	0.3401	0.0843	0.0000	-	-	-	0.3401	0.0843	0.0000
	Distance	-0.0394	0.0036	0.0000	-	-	-	-0.0394	0.0036	0.0000
	Commute time	0.1219	0.0490	0.0130	-	-	-	0.1219	0.0490	0.0130
	Size	0.0011	0.0005	0.0190	-	-	-	0.0011	0.0005	0.0190
	Social personality	0.1347	0.0581	0.0200	-	-	-	0.1347	0.0581	0.0200
	Tendency to use amenities	0.1749	0.0489	0.0000	-	-	-	0.1749	0.0489	0.0000
L2. social capital	Environmental satisfaction	0.4961	0.2789	0.0750	-	-	-	0.4961	0.2789	0.0750
	Entropy	0.3292	0.1436	0.0220	0.1687	0.1035	0.1030	0.4979	0.1079	0.0000
	Distance	0.0103	0.0111	0.3530	-0.0195	0.0109	0.0740	-0.0092	0.0031	0.0030
	Commute time	0.0194	0.0717	0.7870	0.0605	0.0413	0.1440	0.0799	0.0615	0.1940
	Size	-0.0026	0.0007	0.0000	0.0005	0.0004	0.1560	-0.0021	0.0006	0.0000
	Social personality	0.3499	0.0926	0.0000	0.0668	0.0452	0.1400	0.4168	0.0880	0.0000
	Tendency to use amenities	-0.0222	0.0804	0.7820	0.0868	0.0548	0.1130	0.0645	0.0592	0.2760
L3. perceived work performance	Social capital	0.5315	0.0838	0.0000	-	-	-	0.5315	0.0838	0.0000
	Environmental satisfaction	-0.1236	0.2625	0.6380	0.2636	0.1558	0.0910	0.1401	0.2703	0.6040
	Entropy	-0.0720	0.1314	0.5840	0.2226	0.1007	0.0270	0.1506	0.1087	0.1660
	Distance	-0.0068	0.0104	0.5130	0.0000	0.0102	0.9990	-0.0068	0.0033	0.0360
	Commute time	-0.1250	0.0688	0.0690	0.0274	0.0444	0.5370	-0.0976	0.0663	0.1410
	Size	0.0021	0.0007	0.0020	-0.0012	0.0005	0.0100	0.0008	0.0006	0.1660
	Social personality	0.1547	0.0833	0.0630	0.2048	0.0592	0.0010	0.3596	0.0827	0.0000
	Tendency to use amenities	0.0212	0.0763	0.7810	0.0127	0.0541	0.8150	0.0339	0.0641	0.5970

4.3. Model Fit

The values of the fit indexes, including the root-mean square error of approximation (RMSEA) and the standardized root mean square residual (SRMR), evaluate the SEM to be fit. According to the matrix of standardized covariance residuals, the results show that values are lower than 1.96 in the off-diagonal elements, suggesting no substantial areas of model misspecification (Pituch & Stevens, 2016).

For a good square goodness of fit test, significance is considered an indicator of poor model fit. The results show that the chi-square goodness of fit test is significant, $\chi^2(198)=613.97$, $p<0.01$, indicating possible poor model fit, but since this can be caused by only minor misspecification, other fit indices are also reported. The root mean square error of the approximation (RMSEA) value is 0.063, which is considered acceptable (Pituch & Stevens, 2016). The standardized root mean squared residual (SRMR) is 0.072, which is an acceptable fit (Pituch& Stevens, 2016).

5. Discussion

5.1. Types of Mixed-Use Industrial Cluster

In what follows, the types of industrial clusters are categorized according to the level of mixed-use and further grouped based on the addition of “distance from the city center,” an important variable. Among the variables used in the model, “distance from the city center” is vital because amenities in the city are more ambient as it gets closer to the center, increasing accessibility, preference, and convenience. Hence, the location of the industrial cluster has a significant impact on worker satisfaction or performance. The location of industrial clusters is important because they do not exist in isolation but rather in the context of the city, interacting with it. Furthermore, the finding that distance has a high correlation with entropy rather than size or commute time clearly demonstrates the impact of mixed use in each type. Thus, representative cases were investigated using these two variables, which allowed us to qualitatively assess the differences in the degree of entropy in each industrial cluster.

The results show that entropy decreased with distance from the old downtown area. The original city center is within a 5 km radius from its core, the sub-center is located between 5 and 20 km, and the outskirts are more than 20 km (Figure 14). Low entropy industrial clusters are more likely to be single-use, while high entropy clusters are more likely to be mixed-use. The majority of low entropy clusters mainly consist of factories with few parks or other amenities. Nonetheless, the graph shows that the entropy index is not high due merely to its proximity to the city center. For example, even though the Sasang industrial cluster (C2) is close to the city center, its entropy is low because its buildings were mainly constructed for a single purpose. Figure 18 depicts the classified groups by distance: Type1—urban convergence, Type2—function separation, and Type3—urban separation type. In addition, Type1 and Type2 have two distinct subgroups: high entropy and low entropy. Type3 is classified as one group. The characteristics of each group explain why entropy varies and how the effects of mixed-use on environmental satisfaction, social capital, and perceived work performance vary by group.

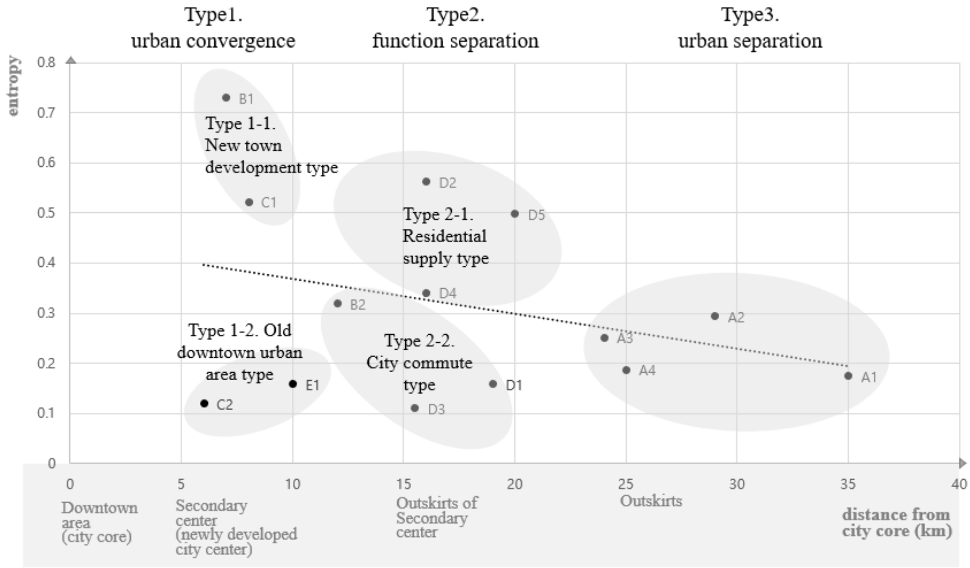


Figure 18 Entropy of Clusters and Its Line of Best Fit

Table 14 Types of Mixed-Use Industrial Clusters

Classification	Sub-Classification	Main Characteristics	Examples
Type 1. Urban convergence	Type 1-1. New town development type	Developed as a "new town" on the edge of the original city center. It is characterized as a newly planned form with high-rise buildings constructed for a variety of functions.	B1, C1
	Type 1-2. Old downtown urban area type	It is located in an expanded part of the existing urban area.	C2, E1
Type 2. Function separation	Type 2-1. Residential supply type	“Residence” is supplied on a large scale rather than diversity of facilities (e.g. apartment complex and housing complex). This is located in a secondary center or outskirts of the sub-center.	D2, D4, D5
	Type 2-2. City commute type	It is non-residence supply type.	B2, D1, D3
Type 3. Urban separation		This type represents an entirely distinct zone for lifestyle. It is not a form in which the urban area is expanded; instead, it is a form that is distinct from the urban area. Some of their surrounding areas have villages, but the industrial cluster contains no dwellings within. This type can be divided into two types based on park presence or absence in individual industrial clusters in the study area.	A1, A2, A3, A4

Table 15 Ratio of Building Uses

Study Area	Entropy	Industry	Commerce	Accommodation	Culture	Education	Medic	Public	Office	Residence	Other uses	Green	Number of Buildings
A1	0.1752	88.38%	0.73%	0.00%	0.00%	0.00%	0.00%	0.00%	0.13%	0.30%	0.29%	10.18%	316
A2	0.2947	77.28%	1.06%	0.00%	0.00%	0.15%	0.00%	0.05%	0.31%	0.15%	3.24%	17.77%	325
A3	0.2524	81.51%	0.99%	0.00%	0.00%	0.02%	0.00%	0.00%	1.05%	0.51%	0.55%	15.37%	549
A4	0.1878	89.68%	1.87%	4.48%	0.00%	0.00%	0.00%	0.00%	0.32%	0.00%	3.64%	0.00%	129
B1	0.7317	7.61%	10.71%	0.91%	4.12%	31.58%	0.21%	0.63%	1.97%	19.89%	22.33%	0.03%	260
B2	0.3205	80.35%	5.17%	0.00%	0.47%	0.00%	0.00%	0.00%	3.74%	0.20%	8.22%	1.85%	86
C1	0.5237	49.70%	5.42%	0.00%	0.00%	0.00%	0.00%	0.00%	3.41%	14.77%	26.70%	0.00%	23
C2	0.1204	94.02%	4.34%	0.02%	0.08%	0.28%	0.00%	0.15%	0.25%	0.16%	0.67%	0.03%	5,008
D1	0.1592	93.93%	1.06%	0.01%	0.11%	0.54%	0.18%	0.06%	0.60%	0.03%	0.38%	3.10%	4,289
D2	0.5630	23.46%	8.85%	1.08%	0.09%	1.34%	0.00%	0.03%	0.00%	52.11%	9.66%	3.39%	1,033
D3	0.1110	94.59%	0.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.89%	0.11%	2.80%	703
D4	0.3416	75.94%	2.37%	0.20%	0.00%	2.43%	0.01%	0.03%	0.12%	1.47%	1.07%	16.35%	1,477
D5	0.4998	60.99%	1.58%	0.00%	0.00%	6.12%	0.00%	0.00%	0.03%	18.06%	9.15%	4.07%	783
E1	0.1592	92.78%	1.96%	0.00%	0.10%	0.13%	0.20%	0.30%	0.90%	0.12%	1.08%	2.43%	3,510

5.2. Effects of Mixed-Use Industrial Cluster

A. Urban Convergence Type

The *urban convergence type* of industrial cluster is more likely to be found in the city's downtown, secondary center, or a newly developed city. Due to its accessibility to downtown, the location has gained a certain amount of popularity among workers.

First, the *new town development type* had the highest entropy index, presenting a complex and highly mixed use. According to the results of the entropy measurement, Centum City (B1) ranked the highest. As Table14 shows, its entropy value of 0.73 is approximately seven times higher than the lowest region (E1) at a value of 0.11. The total number of buildings is 260, which is fewer than in other areas, but each structure and building in Centum City is large and tall. These large structures provide the benefit of being compact efficiently, an urban landscape with skyscrapers, wide streets, and roads, making an image of a big city. These are ideal, especially for high-tech industries, such as information technology, that do not require a large business area. This also explains why, as the results show, the variable X3—designated size— had no significant effect on environmental satisfaction, because the size of the centum city is small in comparison to other areas, but it was the most satisfying to the workers. Therefore, the compact use of mixed-use buildings has a greater impact on worker satisfaction and social activities than the size.

The mixed use gives Centum City the benefit of being attractive. Nearly every building in Centum City has multiple functions. The buildings fill in every 11 categories of building use, as mentioned in Table 15. Lower floors are mainly used for commercial purposes, while higher floors are used for a variety of purposes.

Education, among them, occupied high portions, at 31.6%. Education facilities include universities, elementary schools, middle schools, academies, and other educational-related institutes. There are also job and R&D research centers collaborating with the university, which are not only for young people but also for adults who want to get hired. Centum City has several job-matching centers and start-up assistance centers, making a big difference by giving more job opportunities for workers. They are usually found in a comparatively large industrial cluster, such as Noksan, but not in smaller industrial clusters such as Mium or on the outskirts. Instead, most people find jobs through online websites, which poses limitations.

Besides universities, cultural amenities, such as Busan Exhibition and Convention Center (BEXCO), film, and broadcasting, are concentrated here, along with commercial stores. Thus, there is a high flow of people. A high proportion of students offers inflow into the cluster, adding to and keeping the atmosphere more active while spending their money on local stores. This vitality is primarily attributable to Centum City's proximity to the city core and its design and planning as a business district, providing a conducive economic activity environment. Any facility can be effectively activated in Centum City due to the city's pedestrian-friendly environment, easy access to public transportation, and large foot traffic.

Although workers leave the cluster at the end of the day, the area does not hollow out because of commercial and office emptiness or inactivity at night. People have other things to do aside from work, so the space remains occupied. This is more beneficial in more urbanized and active regions, such as Seoul in South Korea or Manchester in the United Kingdom, than in Busan.

Nonetheless, the greatest benefits for workers of this type are the numerous activities that can take place, all of which have a positive impact on social capital, environmental satisfaction, and work performance. Workers only take breaks at lunch or after work until the stores close. Because the break is short, it is important for them to have a variety of options in walking distance. During the break, individuals may select a building, enter, and consume it, and then engage in a variety of cultural or recreational activities, such as a stroll through the park. Even though people do not engage in particular events, they occasionally run into many events on the street near their workplace, such as pop-up art exhibitions or playing movies on a big screen. An environment with this variety of choices is satisfying and supports the building of social capital through spending time with each other.

When employees have more freedom of choice, they are more satisfied, which impacts their performance. There are numerous other options to commute, including bicycles, automobiles, and public transportation. Three subway stations are located within or near Centum City. Because commuting options vary, workers can also select their preferred type of residence, such as an apartment or a dormitory provided by their company.

Second, the *old downtown urban area type* is closer to the downtown than the new town development type. However, despite being located in the city, it produces different results. Sasang (C1) and Shinpyung Jangrim (E1) are representative cases. This is primarily due to the fact that they were originally built on the outskirts, but as the original downtown area expanded, they became a part of the city. They are typically heavy or light industries that reside in a low-rise building, but there are a few other purposes, such as a park or housing.

Shinpyung Jangrim was Busan's first industrial cluster, designated in 1980s. The scattered and polluting companies, mainly manufacturing, were relocated here. However, as the city's downtown expanded, the rapid residentialization of the surrounding area occurred. Therefore, the cluster is regarded as a polluted area that are avoided by nearby residents. Moreover, newly developed industrial clusters nearby diminish the cluster’s competitiveness.

Due to its origin, the area possesses the lowest entropy value. More than 90% of their building uses are for factories, and the ratio of housing is less than 1%, and green areas are less than 3%. The area is quite large, about 3,021,000 sq. km, which is 2.5 times larger than Centum City. This makes it difficult for workers to walk out of the industrial cluster during breaks or lunchtime to grab lunch, so the employees do not have many things to do within the clusters.

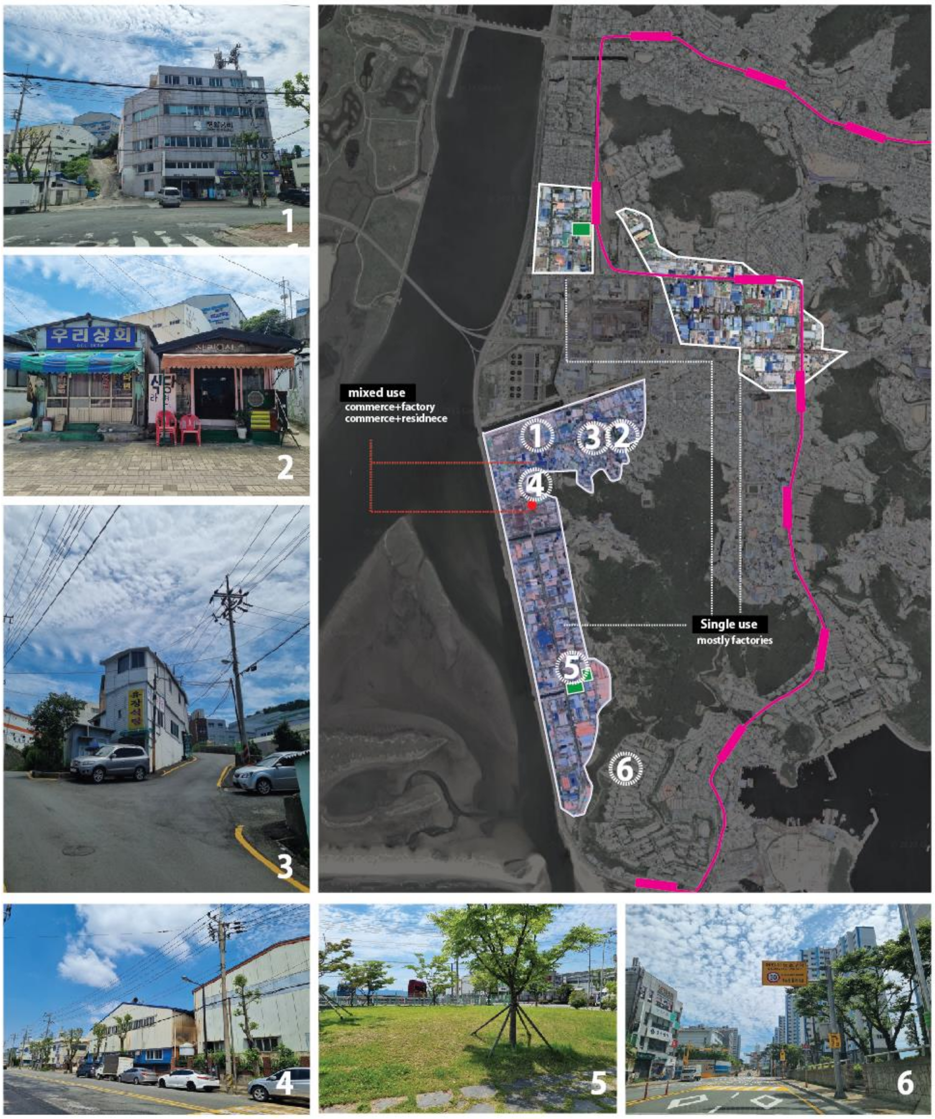
The advantage of this type of cluster is that residential areas are close, but there is a lack of a convenient transportation system from a distance. As many subway stations run through residential neighborhoods, the only subway station stops near are located at the cluster's edge, where it appears to be more for residents nearby. Although there are some bus stations within the cluster, it does not appear to encourage people to use public transportation.

Therefore, mixed use is adopted less efficiently. Due to its age, Shinpyung Jangrim has some repair issues. An issue for pedestrians is that the streets are not friendly to walking because they have mixed up pedestrian paths and car roads. This is because Shinpyung Jangrim was planned in 1980, whereas Centum City was planned in 2000 with more advanced planning knowledge. Shinpyung Jangrim prioritized cars over pedestrians for material transportation. The cluster appears to be correcting this by planting trees and constructing a park, but the old structure has limitations because there is insufficient width to walk on when trees are planted on narrow streets, and the park is quite dull. It also happens to the building’s use. For example, there are convenience stores and restaurants on some of the building's lower floors. However, only workers appear to frequent them because of the low business feasibility that no one else comes in to use them.

1. Workers spend time in a park during lunchtime.
2. Frequent outdoor events are held in public.
3. Several large department stores are located nearby.
4. Bexco holds exhibitions, conferences, and events.
5. Knowledge industry center, a complex building, has companies and supportive facilities.
6. Cultural amenities hold an exhibition of the webtoon and comic book.
7. Broadcasting station gives an additional inflow of visitors.
8. University causes a high inflow of students.
9. Wide and walking-friendly environments on the streets, with the famous movie directors' names on the street.

Figure 19 New Town Development Type – B1. Centum City

Note: The map was redesigned based on Google Earth and retrieved May 7, 2023



1. The most common type of mixed-use is a convenience store and factory.
2. They have small-size commercial stores and restaurants.
3. Pedestrian streets are disconnected, mixed with the car roads, and hills make uneasy access.
4. They have low-rise buildings, and the urban grain is small.
5. A park has low accessibility due to the distance from the factories and ongoing construction nearby.
6. Residential areas nearby have different sceneries, with newly developed buildings.

Figure 20 Old Downtown Urban Area Type – E1. Shinpyung Jangrim

Note: The map was redesigned based on Google Earth and retrieved May 7, 2023

B. Function Separation Type

This type of mixed-use entropy is intermediate overall and is typically found on the outskirts of the secondary city center. Their primary industry is manufacturing, but it can also be a high-tech industry. The variety of lifestyles decreases as there are fewer housing options and fewer stores to visit.

First, the *residential supply type* is still relatively high mixed-use as ranked second, but this is primarily attributable to large residential areas. Within the industrial cluster, there are many residential areas where employees can commute. Other uses, such as retail stores, service facilities, and cultural amenities, are located near residential areas. The factories in Picture 3 in Figure 21 indicate a large car firm. One company, Renault, occupies 23% of the total area. It is made up of a dormitory, a factory, and a large parking lot.

Apart from the factory areas, other areas serve as support systems for other nearby industrial clusters. Therefore, this type of industrial cluster can be satisfying for workers. However, the residential safety of children is quite questionable in manufacturing areas due to the danger posed by heavy engineering-laden trucks or cars. It at least attempted to distance itself from the factories by constructing a thick green buffer zone and six lanes between residential and factory areas.

Although this cluster is comparatively highly mixed use, it lacks public transportation because no subway station passes through the clusters. Thus, commute options are limited. However, the high entropy leads to increased satisfaction, as demonstrated by the results. This suggests that, despite their limited accessibility from public transportation, highly mixed areas can still encourage the socialization and satisfaction of workers more than in other industrial clusters.

Second, the *city commute type* has a lower entropy. This type is primarily associated with heavy industry. For starters, building use is less diverse. Even if there are houses, there are not many of them. The only facilities for the bare necessities are built. As a result, the majority of the employees prefer to commute from the downtown area of Busan. However, the commute to and from work is hampered by heavy traffic during rush hour. Further, because it requires more housing and transportation costs from such a greater distance, it may have a negative impact on environmental satisfaction. Myungji Noksan is an exception because only the Noksan area was measured in this study. Myungji Noksan consists of residential areas in Myungji, which is located in a separate region, and industrial areas are located only in Noksan.

Working conditions for this type are deplorable for running local retail or cultural stores. Although "mixed site" is now possible, allowing all types of stores to be located, primarily in the heart of the industrial cluster, it does not work well due to low business feasibility. They have commercial amenities and a park to give the impression that they have a suitable environment in which to run a business. However, some are still underutilized, and others are constantly for sale. The law still requires at least 50% industrial land area, and the mixed site cannot exceed half of the industrial facility site area, making mixed-use development difficult to implement.

The bigger issue is that people do not want to run their own businesses because they are unlikely to succeed in the *city commute type*. For example, it takes 50 minutes to get to a commercial store in the Mium and Myungji Noksan industrial clusters for a cup of coffee from a company located at the fringe of the clusters. Workers have only one hour during the lunch break to relax, and they have to spend it entirely on travel. As a result, rather than investing in travel time, employees are forced to use the cafeteria or bring their own packed lunches. These clusters create an environment that workers dislike, preferring to change jobs as soon as possible. In fact, there are frequent job turnovers.

1. Large apartment complexes are located.
2. Zones for factories are separated from residential areas.
3. A green buffer zone was made to separate residential areas and factories.
4. Mixed-use of commercial stores are found.
5. Mixed-use of residence and commercial stores are shown.
6. Multifamily housings is shown.

Figure 21 Residential Supply Type – D2. Shinho

Note: The map was redesigned based on Google Earth and retrieved May 7, 2023

1. Large buildings near the central areas are relatively managed well.
2. Park is well-managed. Some people were sitting on the bench.
3. Mixed-use buildings used for commercial buildings are located near the central areas.
4. A common form of mixed-use is a company with a cafeteria.
5. Pedestrian streets are undermanaged, and bushes make it unavailable to walk on them.
6. Large and aged factories are often found.

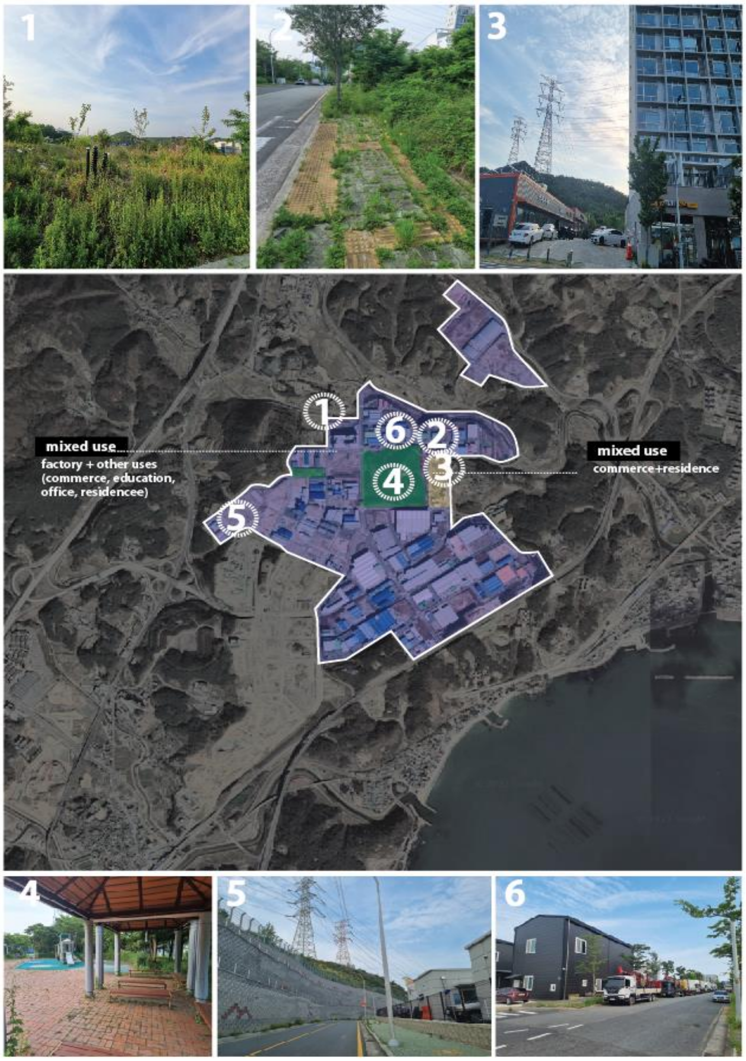
Figure 22 City Commute Type – D1. Noksan
Note: The map was redesigned based on Google Earth and retrieved May 7, 2023

C. Urban Separation Type

Historically, businesses relocated to the periphery because of the low rents fee, large scale, and low-cost land available (Scott, 1982; Zhang & Tang, 2018). This type is mostly found in the manufacturing industry, and these industrial clusters are mostly located on the city's outskirts. It is a separate region from the urban areas, where they represent a different way of life because the surrounding environment is less diverse. There are villages for residence near the cluster, but there is no housing or diverse use within this type of industrial cluster.

Upon closer examination of individual industrial clusters within the designated study area, this type of industrial cluster can be classified into two types based on the presence or absence of a park. Due to their small size, some industrial clusters cannot afford to have a park within them, whereas others can. The existence of parks increases the diversity of a cluster, giving some of them a higher entropy.

As the mixed-use entropy of the industrial cluster decreases, social capital is more likely to decrease. As the results show, more socializing affects an increase in social capital. Socializing primarily happens when people spend time together, such as during breaks or after work, instead of during working hours. The surrounding environment should be supportive for socializing to occur. Within a higher mixed-use industrial cluster, more social activities can take place while using the space in the building. However, the lower mixed use with monotonous landscape offers few places for people to spend their time. Of course, this is different depending on the size of the company or the atmosphere within the company, but the relationship is altered simply by providing ample space for social activities.



1. There are empty spaces designated for residence, but no development has yet been made.
2. Unmanaged pedestrian streets near the mixed-use areas make it difficult to activate the areas.
3. People use mixed-use areas with residential and commercial buildings.
4. Parks are underused.
5. Long walls are constructed around the cluster, disconnecting space.
6. Factories and trucks are filled with the scenes.

Figure 23 Urban Separation Type – A2. Banryong, Busan Advanced Materials, and Jangan
Note: The map was redesigned based on Google Earth and retrieved May 7, 2023

Given that distance between buildings is greater in less mixed-use areas, more cars are used, and walking-related activities are significantly reduced. In factory-dominated outskirt areas, lunchtime is spent traveling to the city center just to get to the restaurant. Even if the restaurants are within the same cluster, the distance is sometimes quite long, necessitating car use. Furthermore, driving in the cluster is also inconvenient because of the insufficient parking lot available, particularly for old industrial clusters in South Korea, where the land is narrow and the infrastructure is aging. People have nothing to do nearby after work, so they rush to return home. However, if the distance is short, representing more mixed use, people can buy a cup of coffee and go for a short walk in the park. This is likely to occur in an industrial cluster located in an active city center, and it would help increase social capital.

Moreover, perceived work performance was found to be more influenced by personal characteristics than by mixed use. Indeed, as the results show, people who prefer to socialize have higher work performance, but high entropy may not have a direct effect on performance. However, as entropy increases, so does socialization, resulting in the building of more social capital. This indirectly results in higher performance, as socializing has an effect on performance.

6. Conclusion

This study responds to recent needs for research on the planning of mixed-use industrial clusters, identifying mixed-use development as the primary dimension of the competitiveness of industrial clusters. While planners have long recognized the value of mixed use in promoting benefits for workers and firms, the effect of mixed use has been the subject of extensive debate in the literature.

Using surveys, spatial analyses, and statistical analyses, the actual opinions of the employees, this study assessed the planning within industrial clusters. The intuitive idea that mixed use brings positive effects was proven, as the results show that industrial clusters benefit significantly from high mixed use by fostering a more satisfying environment, increasing social capital, and boosting employee productivity. This finding is consistent with previous theories that mixed use has an effect on social activity by increasing individual engagement. The discovery regarding environmental satisfaction or work performance is also notable.

Beyond measuring effects, this study further discovered factors that should be considered in the planning of mixed-use industrial clusters for sustainable growth: 1) worker preference, 2) building uses, density, and size, and 3) distance from the downtown areas. Considering these three will make mixed-use even more efficient. For an industrial cluster's sustainable success, industrial clusters should be created to increase worker satisfaction.

First, the preferences of individual workers should be considered. Mixed use is obviously developed for people to use; thus, controlling them to measure the exact effects is necessary. Second, building uses must vary within a high vertical density and in a proper size that does not cause land waste. Centum City, for example, is a densely populated area with efficiently compacted skyscrapers. The building uses in Centum City are highly diverse. Workers in Centum City were pleased because it provided a variety of options and a pedestrian-friendly environment with wide streets and all needs met within walking distance. Third, the distance to the city must be considered. Although an industrial cluster may have a relatively high mixed use, if its location is far from the city center, people may prefer to work near the downtown, where they can spare more leisure time after work.

However, without the three conditions mentioned above, mixed use will cause major problems. For example, Sasang has some old structures that have been converted to mixed-use development using advanced planning ideas. As a result, they have more structures on the streets, which are already narrow for pedestrians, or in mixed-use buildings, which have poor business opportunities due to low non-worker access. Therefore, before implementing mixed-use industrial clusters, the characteristics of industrial clusters must be considered.

The findings of this study provide practical suggestions and implications for urban planners and policymakers, given that mixed-use planning has proven to be an important strategy for many countries, including South Korea. However, the practice of mixed-use planning and construction does not guarantee a positive effect. Controlling disordered expansion or avoiding ineffective plans can improve the competitiveness of the industrial clusters. Notably, the findings do not imply that less mixed-use areas should be demolished. Instead, they all play complementary roles, as each industrial cluster’s characteristics are distinct. This is a spatial division of labor. For example, as a Type 1-1, Centum City has created jobs with a city center oriented with a high value-added industry, attracting talented young people and necessitating industrial convergence. It has gained more popularity through industrial changes in history. By contrast, Type 3, region A2, which is located on the outskirt, seems to be less competitive. Lower-wage workers work, and young people do not prefer them. Nonetheless, they play a vital part in the city, with a large designated size and suitable for manufacturing, which used to be an industry growth engine.

A limitation of the study is that the analyses focused on mixed use in terms of employees within industrial clusters. Future studies should consider the surrounding areas for a full investigation of the effects of mixed use while accounting for the context of the neighborhood.

Chapter 5. Conclusion

1. Research Findings

Industrial clusters have substantial effects on the economy and society, including job creation and employment, investment attraction, supply chain synergies, economic growth and competitiveness, and regional development. Successful industrial clusters constantly adapt and innovate, remaining competitive in an ever-changing global economy; however, others face considerable difficulties or even cease to exist. Many deteriorating industrial clusters worldwide are empty, unsold, and broken, desperately needing a fix. Therefore, it is critical to understand the characteristics that contribute to the success of industrial clusters.

This dissertation performed a comprehensive analysis of the successful growth of industrial clusters by assessing the phenomenon on three different scales: the general approach in the second chapter, the macroscopic approach in the third chapter, and the microscopic level in the fourth chapter. These diverse perspectives provide unique insights and knowledge that collectively enrich the comprehension of the industrial clusters' success.

In Chapter 2, the dissertation identified the three types of life cycles of the growth and decline of industrial clusters by verifying the actual patterns in the process of utilizing resilience. Previous studies have mostly focused on one or two cases chosen from Western countries. However, this chapter generalized theories of industrial clusters' life cycle by proving them with data of the entire official industrial clusters in South Korea, which encompasses a total of 1,375, for the past 20 years. 1) The Malmo-type cluster (496 clusters, 64%) draws a curve that regrows after a decline. This type overcomes a crisis by potentially using all the determinants of resilience, including restructuring, government support, human capital, and location. 2) The Silicon Valley-type cluster (125 clusters, 16%) overcomes its problems and rises again when faced with a crisis instead of experiencing a decline or collapse. Resilience here is mainly driven by human capital and government support, along with other factors. 3) The Detroit-type cluster (148 clusters, 19%) overcomes some crises in the short term, but it clearly declines in the long term. The main problem is their poor utilization of resilience, which is commonly caused by a single industrial structure.

Chapter 3 presents the interrelationships between clusters and their city's settlement characteristics in terms of how these characteristics influence each other and lead to employment growth in the cluster. This study expands on ideas about the role of cultural amenities in industrial clusters that lack transport options and have insufficient accessibility, over-engineered roads, and fancy facilities. The city's role in industrial clusters is important because it serves employees' needs left unserved by industrial districts, but this relationship has not received sufficient attention in previous research. Despite the widespread belief that commerce and service indicators are critical for employment growth, this study demonstrates that cultural variables contribute the most to cluster employment growth. Prior findings are supported to some extent, as cultural amenities were shown to have a more significant positive effect on the growth of cluster employment than education, commerce, or service indexes. A new approach was taken from the perspective that industrial clusters can grow through interactions with other city amenities to improve city quality and attract employees. Representative cities, such as Changwon and Cheongju, have rich cultural amenities, and the results confirmed that employment has increased accordingly in these cities.

In Chapter 4, this dissertation examined the effects of mixed-use environments on employees regarding environmental satisfaction, social capital, and work performance. The concepts of mixed-use environments, including industry, residence, commerce, culture, and leisure, together within an industrial cluster, have recently gained popularity worldwide. Even though mixed-uses effects have historically been controversial, this concept has been applied as a hasty prescription for the decline or development of new industrial clusters with expectations of positive outcomes. The findings in the chapter show that it is critical to create a mixed-use environment in order to manage the cluster's limited allocated area successfully and effective land use and building layout for business improvement. This environment enhances the competitiveness and investment value of an industrial cluster. To develop an industrial cluster for mixed-use for sustainable growth, this study presents a strategy that takes into account essential features, such as workers' preference choice, building use, density, and size, and distance from the city center. This shows that industrial clusters' competitiveness can be improved by preventing disorderly expansion or misplanning through mixed-use development.

2. Research Implications

The findings of this dissertation have important implications for urban planners, policy makers, researchers, and businesses who are interested in enhancing the performance and sustainability of industrial clusters worldwide. The findings offer insights to enable informed decisions, such as effective spatial organization and sustainable development, by optimizing land allocation and creating an environment conducive to flourishing industrial activities. They can evaluate their current status, strengthen their weaknesses, and avoid failure based on the findings of this dissertation. Chapter 2 presents the types of lifecycles, a classification method that can be applied to other countries. By correctly identifying their types, planners can benchmark other successful cases within the same group. The resilience of the clusters can be enhanced by analyzing the characteristics of other industrial clusters. Further, Chapter 3 and 4 provide suggestions on how to strengthen resilience from comprehensive points of view, including microscopic and macroscopic approaches.

Regarding policy implications, this dissertation supports legitimacy and important implications for the future direction of projects or development. The effect of amenities and the mixed use disclosed in this work suggest that being located in an area with a well-developed settlement environment is important for the success of industrial clusters. The findings in Chapter 3 suggest that the role of city settlement characteristics should be considered in the growth of industrial clusters. The study highlighted cultural amenities as among settlement characteristics that have the greatest impact on employment, indicating which amenities should be emphasized before developing industrial clusters. The findings in Chapter 4 encourage to adopt mixed-use environments to bring positive results to workers, as demonstrated by the various effects resulting from the degree of mixed use.

This dissertation makes significant contributions to the literature, which needs more theoretical and statistical proofs to support implementing new policies. As the Korean version of the New Deal policy, the Ministry of Land, Infrastructure and Transport (2020) promoted a huge project "Urban Convergence Special Zone", to create high-density convergence areas as a base for regional innovation growth in the center of provincial cities. Such plans have been popular for decades and can be found in many other countries. However, there is a lack of sufficient evidence to suggest whether the outcomes of implementing policies are positive. Moreover, the government has attempted to locate a residential area in the industrial cluster to maintain mixed use and improve the distance between residential and work areas. In fact, some of them failed in cities where settlement environment in surrounding areas was not properly secured, resulting in awkward coexistence. Consequently, nowadays, industrial clusters tend to be located in prosperous areas, such as urbanized areas or university campuses. The findings and implications from each chapter of this dissertation suggest a comprehensive approach to deciding where and what to include in the development of industrial clusters.

This dissertation also suggests strategies for increasing employment in industrial clusters that are experiencing a lack of employees, including those from a younger population. Especially in Korea, considering the given distribution of current young workers, young populations are heavily concentrated in Seoul, which has only three industrial clusters, leaving approximately 1,300 industrial clusters in suburbs or remote areas of Seoul. Further, most industrial clusters in Korea have heavily relied on manufacturing for several decades, which is an unpopular industry among the young population because of the 3D phenomenon (they do not want dirty, difficult, and dangerous jobs). This has also led to serious depopulation problems in some cities. Therefore, the presence of young populations is also critically affecting the revitalization of outskirts areas. The influx of foreigners is probably a good strategy; however, stakeholders should identify ways of increasing the number of people in the area, particularly youth, since the government heavily invests in industrial clusters. Chapter 3 shows the importance of city amenities, and Chapter 4 offers examples of local areas where there is a lack of employees, to show that mixed-use industrial clusters are critical in those areas.

Regarding its methodology and data, this dissertation presents significant contributions in that it used various and improved data and methodology, yielding richer implications compared to previous studies that had difficulty producing appropriate results to support policies. In Chapter 2, the dissertation adopted relatively new methods such as DTW analysis and clustering, whereas Chapter 3 showcased panel VAR in the analysis of the effects of the clusters while considering other interrelationships. Chapter 4 presented a survey, EFA, and SEM. In Chapter 2, the trend of the clusters' life paths was calculated using a classic time series decomposition method, and DTW was adopted to measure the similarity between the paths. The panel VAR methodology was used in Chapter 3 to compensate for the lack of explanation of time series change in previous studies due to conducting their analyses at a fixed time point. In Chapter 4, SEM and survey methods were used to propose the results of the effects while considering characteristics such as worker preference, building use, density and size, and distance from the city center. These diverse methods support the theories of industrial clusters from various approaches.

The findings of this dissertation have broader implications beyond South Korea and can be applied to industrial clusters worldwide. In other words, the research results and their conclusions are not limited to a specific geographic location or industry, as they can be relevant and useful for understanding and improving industrial clusters globally. The insights gained from analyzing the specific industrial clusters in South Korea can be generalized and applied to similar clusters in other countries that are considering implementing similar initiatives to foster economic growth and development within their own industrial clusters.

Although certain industrial clusters have been unable to sustain or gain popularity, they must be repaired rather than abandoned, especially if they are situated in remote and undesirable areas and are substantially damaged. These abandoned places are still needed; therefore, unpopular clusters should not be viewed as a failure, but rather as an opportunity to look back and become better. Protecting industrial clusters, which can produce additional employment in the surrounding regions, and conserve people's hometowns, can be beneficial in reviving dying cities.

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Chapter 2

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Chapter 3

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Chapter 4

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Abstract in Korean

생애주기 변화, 도시시설과 복합용도 환경이 산업 클러스터의 성공에 미치는 영향

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본 연구는 산업 클러스터의 생애주기, 도시시설 및 복합용도 분석을 통해 산업 클러스터의 성장에 기여하는 특성들을 탐구하고자 하였다. 산업 클러스터는 건실한 경제성장의 주역이 되기도 하지만, 불가피한 성장 둔화와 쇠퇴를 겪으며 도시의 기피공간으로 전락하기도 한다. 산업 클러스터란 특정 산업들이 지리적으로 밀집한 형태로, 상당한 국토면적과 재정 투입을 필요로 하며 주변 지역의 경제등락까지 확대되는 파급력을 갖고 있어, 도시계획에서도 중요한 부분을 차지한다. 본 연구는 산업 클러스터의 성장 요인을 미시적•거시적으로 접근하여 다각도의 공간단위에서 산업 클러스터의 장기적 성장을 위한 시사점을 밝히고자 하였다.

2 장에서는 클러스터의 삶에 대한 이해를 통해, 성장과 쇠퇴의 원인을 분석하였다. 한 국가의 전체 산업 클러스터인 1,375 개를 대상으로, 생애주기 유형분류에 따른 각 그룹의 성장과 쇠퇴 경로를 정량적으로 이해하고, 위기에 대응하는 공통적인 나타나는 양상을 회복탄력성의

관점에서 분석하고자 하였다. 본 연구에 주된 분석대상인 한국의 산업 클러스터는 국가주도 성장, 높은 수출 의존도과 같은 특성이 있어 국내•외 정세 변화, 경제 변동, 재난과 같은 동향에 민감하게 영향을 받는다. 클러스터의 상황을 시계열로 그린 후, 동적 시간 워핑(DTW)을 사용한 유사도 측정, 클러스터링을 통해 시계열 그룹을 분류하여 패턴을 일반화하였다. 이후 회복탄력성을 결정하는 요인인 산업구조, 인적 자본, 정부정책 및 지원과 같은 특성들을 정성적으로 분석하여, 회복탄력성 개념을 사용한 지속적 성장의 가능성을 제시하였다.

3 장에서는 산업 클러스터를 바라보는 시선을 외부로 이동하여 거시적인 관점으로 도시 단위로 분석하였다. 산업 클러스터가 쇠퇴할 때, 일반적으로 재정지원, 노후 기반 시설 개선, 도로 확장 등 클러스터 내부 투자 위주의 대응이 이루어진다. 그러나 클러스터 내부에만 투입되는 임시 처방만으로는 장기적인 성장을 이끌어내기 어렵다. 산업 클러스터는 위치한 도시의 성장과 상호작용하며 영향을 받기 때문이다. 외곽에 위치한 클러스터일수록 상업•서비스시설 등 필수요소는 갖추고 있으나, 문화시설과 같이 젊은 근로자 유치에 필수적인 도시시설은 유치하기 어렵다. 문화시설은 도시 분위기를 밝히고, 활기차게 유지하며 근로자의 주거만족도를 높인다. 도시는 산업 클러스터가 자체적으로 제공하기 어려운 문화시설•서비스를 충족시켜 산업클러스터의 안정성과 성장을 이끈다. 이 장에서는 패널 VAR (Panel Vector Autoregressive) 분석을 통해 문화시설이 클러스터 고용 증가에 가장 크게 기여한다는 점을 밝히고, 다른 도시시설인 상업, 서비스, 교육의 유입을 촉진하고 상호작용하여 도시 품질을 개선하고, 그 결과 긍정적인 영향을 미쳐 성장할 수 있다는 관점으로 새롭게 접근하였다. 도시 시설과의 상호작용을 통해 산업 클러스터가 성장할 수 있다는 점을 새롭게 접근한 것으로, 대표적으로 창원, 청주 등의 도시는 풍부한 문화생활권과

함께 다른 도시시설도 함께 유입되었으며, 이에 따라 고용이 증가했음을 확인할 수 있었다.

4 장은 미시적인 관점에서 클러스터의 내 복합용도 개발이 주는 성장효과를 분석하였다. 최근 국내외에 클러스터 내 산업, 주거, 상업, 문화, 레저를 모두 갖춘 복합단지 개념이 증가하고 있다. 클러스터의 제한적인 지정면적을 효율적으로 관리하기 위해서는 복합용도 환경의 도입이 중요하며, 효과적인 토지이용, 업무향상을 위한 건물 배치는 산업 클러스터의 경쟁력과 투자가치에 영향을 미친다. 산업 클러스터의 복합용도 정도에 따른 효과는 업무능력, 사회적자본, 환경적 만족도에서 측정될 수 있다. 이 연구에서는 지속가능한 성장을 위해 복합용도로 개발된 산업클러스터를 조성할 때 1) 근로자 선호도, 2) 건물 용도, 밀도 및 크기, 3) 도심과의 거리 등의 특성을 고려한 계획을 제안하였다. 복합용도개발을 통해 무질서한 확장이나 잘못된 계획을 통제함으로써 산업 클러스터의 경쟁력을 높일 수 있다는 점을 시사한다.

본 연구는 산업 클러스터 이론들을 보다 다양한 방법론과 데이터를 바탕으로 분석했다는 점에서 진보된 면이 있다. 이전 연구에서는 잘 다루지 못한 풍부한 방식으로 증거들을 생산했다. 시계열 및 DTW 분석이나 패널 VAR 이나 설문조사, 구조방정식과 같은 방법론들을 사용해서 한국 전체 산업 클러스터들을 같은 모델 안에서 분석할 수 있는 방식을 취했다. 그리고 이 연구가 산업 클러스터의 1,375 개의 데이터를 대상으로 시계열 형식으로 데이터 수집, 가공, 분석에 사용하여 이론에 접근했다는 점도 한국에서 선제적으로 시도된 부분이다.

이 연구는 산업 클러스터 이론과 정책이 효과적으로 실현되기 위한 근거를 마련하였다는 점에서 큰 시사점을 갖고 있다. 한국에서는 클러스터 내 기업과 주거시설이 조화된 직주근접형 환경을 조성하려는 시도가 있었으나, 주변에 정주환경을 제대로 갖추지 않은 상태에서 어색한 공존으로

남게 되어 긍정적인 효과를 낳지 못했다. 이에 최근에는 이미 잘 갖춰진 도시환경에 산업 클러스터를 배치하는 방법을 추진하고 있으나 이를 실행하기 위한 이론적 근거가 미흡하였다. 본 연구는 정주환경이 제공하는 효과를 데이터를 통해 증명함으로써 대규모 프로젝트를 시행하기 위한 이론적 토대를 제공했다는 의의가 있다.

주요어: 산업클러스터, 산업단지, 생애주기, 회복탄력성, 정주환경, 도시시설, 복합용도개발, 산업쇠퇴, 산업성장, 경제개발, 한국

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