Spatial Analysis of Urban Structure Changes in Korean Mega-Cities

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Abstract

This study aimed to analyze spatial changes and structural transformations in five Korean mega-cities using populations and the number of tertiary industrial workers as variables. The authors grouped together and chose to study five mega-cities, Seoul, Busan, Gwangju, Daegu, and Daejeon, in Korea. Previous studies only focused on one city or region, thus offering a limited analysis. This study used the data from the Population and Housing Census, performed in Korea in 1995, 2000, and 2005. The authors also used the number of tertiary industrial workers from the Census on Basic Characteristics of Establishments in Korea for the years 1995, 2000 and 2004.

Three methodologies were used to analyze spatial structural changes in the five mega-cities: 1) induction transit density analysis to separate city centers from sub-centers, 2) spatial statistics using the Gini coefficient and the standard distance to measure concentrations and dispersions of populations, and 3) spatial analysis to identify the effectiveness of spatial changes using the inverse distance weighting (IDW) method in GIS.

The features of the five mega-cities can be summarized as follows. First, there was suburbanization and concentration of the populations, and second a spatial de-correlation between the population and the establishments.

Keywords: Mega-cities; urban spatial-structure; Gini coefficient; standard distance; IDW

1. Introduction

1.1 Urban Spatial Structure

A city is a spatial domain that is defined by its boundaries and its spatial formation is determined by all of its components. Generally, the word 'structure' includes the arrangement of and the interrelationships among the components. Urban spatial structure has been an interesting subject to study for diverse academic fields including Urban Engineering, Urban Administration (Kim, 1993), Urban Economics (Griffith, 1981; Eldridge, 1984), Regional Development (Clark & Wilson, 1983), and Urban Geography (Jin, 1983). Such varied disciplines create a range of opinions for the definition of a city.

Dynamic spatial structure changes mean alterations in the equality of the spatial elements and the immigration and diffusion of the urban core. In this regard, dynamic changes in spatial structures are easily estimated when using spatial statistical models.

An urban center is a key factor in the identification of a city. Historically, every city had one or more places where its pivotal activities were concentrated. These places have been repeatedly described as an urban core, urban center, or central business district (CBD).

A CBD is a societal location that has the characteristics in socio-economic terms of a high population density and conspicuous social heterogeneity. An urban core or CBD is typically defined by its population growth rate, or population density, and its tertiary workers.

1.2 Factors Influencing Urban Spatial Structure

Urban spatial structure is not established by one factor, but rather by comprehensive and complex factors that are influenced by historical and traditional elements (Kim, 1993). These factors include increases in population, advances in transportation and telecommunication, changes in social activities, and changes in local government policies.

Therefore, urban spatial structure is different for each city just as their features and characteristics are different; further investigation will reveal these
differences. Comprehensively, urban spatial structure is regarded as a system made up of diverse factors and components.

The factors that influence changes in urban spatial structures vary, but there are some critical factors. The first, and most critical, is the economic factor. Urban economists stress economic factors since urban spaces are created and influenced mostly by solvency that pertains to land price or rent (Chapin & Kaiser, 1979). Social factors are the second critical factor in urban spatial structure. Chapin discovered a tendency for urban spatial change using ecological factors. These factors include concentration and decentralization, invasion and succession, superintendence and segregation. The third concerns political factors. It places its emphasis on public interest, while economic and social factors focus on open competition.

1.3 Research Aims
To be more accurate in analyzing spatial structural changes, components used to organize a city should be considered. This study reflects on the components of a city that preceding studies have not taken into account.

This research will analyze the changes in the urban spatial structures of Seoul, Busan, Gwangju, Daegu, and Daejeon. These five mega-cities are representative of Korean metropolitan cities. They are also likely to reflect features in spatial-structural change, since they were developed by focused developmental plans and policies.

2. Methodology
2.1 Data Collection
Data was collected from the Korean Population and Housing Censuses of 1995, 2000, and 2005. The authors also used the number of tertiary industrial workers from the Census on Basic Characteristics of Establishments in Korea for the years 1995, 2000, and 2004.

The digital maps of 'Eup, Myun and Dong', the smallest units of the Korean Administrative Zone, were used in this study and were processed according to the boundaries of 2003. Therefore, the number of Eup, Myun and Dong in Seoul were estimated at 522, 221 in Busan, 138 in Daegu, 85 in Gwangju and 76 in Daejeon, with a total of 1,042.

To analyze changes in the urban spatial structure, the authors needed the number of establishments and employees, the population, and the physical measurements of Eup, Myun, and Dong. Establishments and employment data were taken from the Korean Census on Basic Characteristics of Establishments for the years 1995 to 2004, published by the Korean National Statistical Office. Population data was taken from the Korean Population and Housing Census for the years 1998 to 2005. Physical measurements were gathered using Arc GIS software.

2.2 Methods
This study established a methodology to analyze urban spatial structure through investigating typical cities and then applied such data to the empirical studies in order to analyze urban spatial structure.

This methodology distinguishes and analyzes the centers and the sub-centers in each mega-city using induction transit density (ITD) based on interaction potentials. As in Jeon (1995) and Gordon (1989), this study also used ITD to distinguish between sub-centers based on interaction potential. The interaction potential is described as a total amount or volume of induced trips. The density of the induced trips was measured by dividing the total amount by the area of the unit.

| Total Counts of Transit Induction |
|----------------------------------|
| = (Transit induction in each business * Number of employees of each business)/Area of the zone |

If the density was measured, it then had to be standardized into a Z-score. If the Z-score of an area was greater than 0.8, it was regarded as a center.

\[
Z_i = \frac{(D_i - MD)}{SD}
\]

\[D_i = \text{Density of the induced trips of each area } i\]

\[MD = \text{Mean of } D\]

\[SD = \text{Standard deviation of } D\]

Secondly using inverse distance weighting (IDW), this study showed how and by how much population and employment influence urban spaces. To predict a value for any unmeasured location, IDW uses the measured values surrounding the prediction location. Those measured values closest to the prediction location will have a greater influence on the predicted value than farther away values. Thus, IDW assumes that each measured point has a local influence that diminishes with distance, hence the name inverse distance weighted.

Lastly, centers were evaluated to see if the change was centralized or decentralized based on several spatial statistics including the Gini coefficient. This analysis estimated inequality using the Gini coefficient, centralization using the standard distance and decentralization using the mean center, and the direction of spatial developments based on the populations of Eup, Myu, and Dong.

3. Results and Discussions
3.1 Seoul
The annual center count was estimated as 56 in 1995, 60 in 2000, and 53 in 2004. During the years 1995 to 2000, the total count increased by five, but decreased by seven from 2000 to 2004.

Employees in those centers and sub-centers were occupying 37.21% of the city in 1995; this occupancy increased to 38.9% in 2000 and slightly decreased to 38.76% in 2005. The population was estimated to be 612,697 people in 1995, 897,961 in 2000, and 889,636 in 2004. This pattern is similar to that of employment. During the period from 2000 to 2004, existing central locations had maintained their population centrality,
Centers and Sub-centers Distinguished by Induction Transit Density

Changes in the Spatial Influence of Population in Seoul (IDW)

Changes in the Spatial Influence of Employees in Seoul (IDW)

1995

1995

1995

2000

2000

2000

2004

2005

2004

Standard Deviation Distance, Standard Deviation Ovals and The Direction of Spatial Development in Seoul

Standard Deviation Distance, Standard Deviation Ovals and The Direction of Spatial Development of Tertiary Workers in Seoul

Fig. 1. The Results from Three Methods of Spatial Analysis of Seoul (The Other Areas were not Included Due to Limitations of the Paper)
but the populations in sub-centers declined.

Especially, sub-centers in the northern areas declined, while those in southern areas increased. In 1995, areas with a higher spatial effectiveness were gathered around central areas in Seoul. This situation indicates that many people moved from central areas to outer areas for some reason. The effectiveness of tertiary workers has nothing to do with that of the population.

In 1995, there was no suburbanization. The situation was almost the same in 2000, but the centralization was weakened. The distinctive change in 2004 had to do with an immigration of workers into the west-southern sub-centers. This movement happened as a result of the government trying to develop industrial complexes that focused on information technology.

Since 1960 Seoul has experienced rapid urbanization and industrialization. However, it had been developing from a mono-nuclear structure to a multi-nuclear structure since 1980 and in 1990 finally transformed into a multi-nuclear structure. In 2000, the southeastern areas were rapidly developed, resulting in an inequality and imbalance between the northern and southern areas. Centers and sub-centers tended to diffuse outward from the old districts because the land prices in the developed areas remained higher than the commuting expenses in suburban areas.

Seoul, the capital of Korea, has played pivotal roles in this transmigration. This movement changed the concentration of the population, as well as changing the industries, the economy, and the ethnicity, and Seoul became saturated due to such changes in concentration. Some businesses and establishments found no room to grow as regulations came into effect, while changes in spatial structures were condensed from urban centers into sub-centers.

3.2 Busan

The annual center count was estimated at 13 in 1995, 17 in 2000, and 11 in 2004. During the years from 1995 to 2000, the total count increased by four, but decreased by six from 2000 to 2004.

Employees in those centers and sub-centers were 186,468 in 1995, increased to 179,335 in 2000, and thereafter slightly decreased to 158,415 in 2005. The population was estimated to be 132,782 in 1995, 124,247 in 2000, and 84,712 in 2004. The population changes are similar to those seen in the employment trends.

In 2000, the number of dongs in the centers was estimated at ten, which is an increase of two from the eight present in 1995. The number of workers in the center decreased by 33,000 to 93,965, while the area of the center expanded from 3.331 km$^2$ in 1995 to 4.08 km$^2$ in 2000. The population also decreased from 57,284 in 1995 to 49,649. These changes imply that businesses and establishments diminished within the centers.

Busan changed in a manner similar to that of Seoul. The population of Busan during the period from 1995 to 2000 tended to immigrate outward according to suburbanization and to be dispersed, creating new sub-centers, while tertiary workers immigrated in almost the same manner. Busan has a multi-nuclear structure and has no centralized population; therefore it has already experienced urbanization and has entered the post-urbanization phase.

3.3 Daegu

The number of dongs in Daegu that had a Z-core of more than 0.8 was 22 in 1995, 27 in 2000 and 21 in 2004. So there was a five-dong increase from 1995 to 2000, but a six-dong decrease in 2004 compared to 2000.

In terms of spatial change, the city center in Jung-gu formed as a large core area in 1995. Although there was not much change in this area, the population density increased from the center to the perimeter of the core area in 2000. However, in 2004 the population density was decreasing in the periphery of the city center, and was again becoming concentrated in the city center.

The city centers in 2000 were formed with nine administrative district dongs in total. This total was an increase of two administrative district dongs added after 1995. The number of workers in establishments in 2000 was dramatically reduced to 26,881 compared to the number in 1995. Although the increase was relatively small, the city area was increased from 4.72 km$^2$ to 4.87 km$^2$. The sub-centers were formed with 18 administrative district dongs connected to six centers. The city centers in 2004 had only six administrative district dongs, because three administrative district dongs were excluded compared to 1995. The area was reduced to 3.79 km$^2$, but the number of workers in establishments almost doubled to 40,705. However, the population dropped to less than half that of 2000, from 107,318 to 41,490.

The spatial impact on the population and the number of tertiary industrial workers in establishments were analyzed chronologically. In terms of population, there were a few distinctive factors concerning the changes from 1995 to 2005. First of all, the number of city centers and sub-centers increased from 1995 to 2000 and spatially the population spread uniformly. However, in 2000 the population again became concentrated.

Interestingly, the change in the spatial impact of the tertiary industrial workers was dramatic. In 1995 they were concentrated in the city center, but moved to the west in 2000, only to move back in 2004. This phenomenon can be compared to the decrease in the number of workers in establishments. Gradual suburbanization and decentralization changed with respect to periodic conditions such as economic recessions.
Using the data obtained after the 1990s a change was noted in the urban spatial structure of Daegu. The number of city centers and sub-centers increased from 1995 to 2000 then decreased until 2005. This change represents the population movement toward the suburbs after the 1980s up until 2000. It also shows that the centralization in the suburbs happened while the number of city centers and sub-centers decreased in 2005.

Likewise, Daegu has a topographical limitation regarding growth as a city, and this fact limits it as a metropolitan city. This growth limitation supports decentralization and transition to suburban areas rather than the typical development pattern of city centers. Daegu will therefore continue to experience suburbanization.

3.4 Gwangju

In Gwangju, there was not much of a change in terms of the number of administrative district dongs as there were nine in 1995 and ten in both 2000 and 2004. These dongs were within the researched areas that had Z-scores of more than 0.8 between 1995 and 2004. Also, the change noted in the number of workers in establishments in the city centers and sub-centers that had a Z-score of more than 0.8 was similar to the change in the number of administrative district dongs. The numbers of workers in establishments were 99,035 (29.52%) in 1995, 100,101 (26.48%) in 2000, and 100,091 (25.02%) in 2004.

An examination of the city centers and sub-centers reveals that ten administrative district dongs formed one city center in 2000, and that the number of employees in the city center increased to approximately 100,101. This is about a 10,000 person increase compared to 1995. There was also an increase in the area of the city, from 1.14 km² in 1995 to 8.16 km² in 2000. However, the population in 2000 dropped to 80,934 compared to that of 1995.

There was one city center and one sub-center in 2004. The city center was constructed with nine district dongs, and the sub-center was in an administrative district dongs. There was a small increase in the number of employees in the city center in 2004 compared to 1995 and 2000. However, the land area decreased to 7.77 km².

The spatial effectiveness of the population and the tertiary industrial workers using IDW interpolation showed that in 1995, the suburban administrative district dongs had a greater spatial effectiveness compared to those of past city centers. The spatial effectiveness in terms of the tertiary industrial workers was great in the city center in 1995. This tendency continued from 2000 to 2004 as it spread to suburban areas, except that it was more concentrated in the city center relative to the population. The population had a stronger tendency toward suburbanization and decentralization rather than toward business.

In Gwangju the population was at the stage of absolute decentralization, while business (employment) was at the stage of relative decentralization with respect to the city’s development and the population and employment have been decreasing in the city center. Because of such decentralizations of population and employment a new city center was being formed. Decentralization of the population was happening prior to the decentralization of employment, occurring initially in the old city center's first peripheral area from 1995 to 2000 and increased to the second peripheral area in 2005.

3.5 Daejeon

Among the city centers and the sub-centers that had a Z-score of more than 0.8 in Daejeon, the number of administrative district dongs totaled nine in 1995 and 13 in 2000. However, it had decreased by three by 2004.

In these areas, the number of workers in establishments in 1995 was 106,646 (29.23%) and in 2000 was 98,740 (27.30%). Therefore, the number of workers in establishments decreased, whereas the number of administrative dongs increased. In 2004, however, the number of workers increased to 101,023 (26.18%).

In 2000 one city center was made up of ten administrative district dongs and three sub-centers. In 2000 employment in the city center decreased to 8,845 compared to 1995 and the area of the city center increased from 6.81 km² in 1995 to 9.12 km² in 2000. The population in 2000 was 133,762, an increase relative to 1995. In 2004, this same city center was made up of four dongs, and two sub-centers were

Table 1. Summary of the Spatial Statistics of 5 Cities

| Classification | Population | Tertiary workers | Average increase |
|---------------|------------|------------------|------------------|
|               | Year 1995  | Year 2000        | Year 2005        | 95-05    | Year 1995 | Year 2000 | Year 2004 | 95-04    |
| Seoul         |            |                  |                  |         |           |           |           |          |
| Gini coefficient | 0.452      | 0.435            | 0.438            | 0.31    | 0.601     | 0.569     | 0.564     | 0.70     |
| Standard distance      | 9228       | 9970             | 9988             | 0.79    | 8219      | 8452      | 8572      | 0.47     |
| Busan         |            |                  |                  |         |           |           |           |          |
| Gini coefficient | 0.711      | 0.693            | 0.686            | 0.36    | 0.791     | 0.762     | 0.76      | 0.44     |
| Standard distance      | 7804       | 7952             | 8001             | 0.25    | 7099      | 7390      | 7471      | 0.57     |
| Daegu         |            |                  |                  |         |           |           |           |          |
| Gini coefficient | 0.798      | 0.764            | 0.756            | 0.54    | 0.865     | 0.824     | 0.814     | 0.67     |
| Standard distance      | 6677       | 7040             | 7233             | 0.8     | 5698      | 6109      | 6238      | 1.01     |
| Gwangju       |            |                  |                  |         |           |           |           |          |
| Gini coefficient | 0.805      | 0.769            | 0.759            | 0.59    | 0.87      | 0.829     | 0.806     | 0.85     |
| Standard distance      | 4922       | 5174             | 5232             | 0.61    | 4120      | 4610      | 4804      | 1.72     |
| Daejeon       |            |                  |                  |         |           |           |           |          |
| Gini coefficient | 0.754      | 0.731            | 0.736            | 0.24    | 0.819     | 0.758     | 0.76      | 0.83     |
| Standard distance      | 5341       | 5631             | 5522             | 0.33    | 4860      | 5287      | 5244      | 0.85     |
identified. The number of employees in the city center was 36,792. This value is lower than the number of employees found in Seo-gu (the western part of the city), one of the sub-centers. Also the area of the city center decreased drastically to 3.67 km$^2$. The rank of induction transit density in Seo-gu, as one of the sub-center's most important administrative district dongs, increased dramatically relative to that of the year 1995.

The authors analyzed how the population of Daejeon and the number of tertiary industrial workers impacted the spatial effectiveness through IDW interpolation. In the case of the population in 1995, centralization of the old city center was avoided, since there was a tendency to spread. In 2000 this tendency was stronger and decentralized and in 2005 it became more evident, while the population decentralized to the periphery of the region rather than in the city center of Daejeon.

The city center and the sub-center had a tendency to move to the periphery of Daejeon from 1995 to 2000. This movement was due to the new developments in the periphery of the city because there were size restrictions regarding land use in the old city center; there was also a demand for housing. As the demand was fulfilled through new development, there was a reduction in the number of city centers and the sub-centers from 2000 to 2005, when the numbers stabilized. On the contrary however, the number of workers in establishments from 1995 to 2000 decreased, while the population increased. The number of workers in establishments then increased during 2000 to 2005 whereas the population had been decreasing during these years. The spatial effectiveness of the population and of the tertiary industrial workers showed similar tendencies regarding change to those of the city centers and the sub-centers.

4. Conclusion
This study analyzed spatial structures in five mega-cities by separating city centers and sub-centers and using spatial effectiveness and spatial statistics based on populations and numbers of tertiary industrial workers in each mega-city. To give more accuracy to the analyses of spatial structural changes, one should consider some of the components used to organize a city. This study is significant in that it analyzed components of city organization that other existing studies have hardly taken into account.

This fundamental study initiated efforts to understand the problems and the issues in mega-cities in Korea concerning how the mega-cities have changed and to analyze fundamental features.

This study adopted three methodologies to analyze the spatial structural changes in five mega-cities. Induction transit density analysis was used to distinguish city centers from sub-centers. Spatial statistics using the Gini coefficient as well as the standard distance to measure concentration, dispersion and spatial effectiveness were used to identify changes using IDW in the geographic information system (GIS).

Based on the results, the features of the five mega-cities can be summarized as follows. The first feature is the suburbanization and concentration of the population. The population tended to be suburbanized in most mega-cities from 1995 to 2000, whereas establishments tended to be centralized. This change was due to a large part of the population moving to suburban areas because of increased land prices and expenses in the central city during the period. Further suburbanization in 2005 brought about the diminution of centers and sub-centers. Nevertheless the population was steadily increasing, which continued to drive people out to the suburban areas.

According to the authors' analysis, cities that accommodated immigrants earlier tended to undergo suburbanization during the period from 1995 to 2000. The suburbanization forced people out into suburban areas, increasing the population in those areas and giving birth to new centers and sub-centers in suburban areas from 2000 to 2005.

Spatial de-correlation between the population and the establishments was the second feature of note. The population tended to be suburbanized and dispersed centrally in most of the mega-cities, while workers tended to be concentrated in the central areas of the cities. This arrangement explains that population and establishments have less in common in terms of spatial relationship. Although establishments were slightly dispersed from 2000 to 2005, the extent of the decentralization was insignificant compared to the population. This decentralization resulted from establishments being forced to locate in the centers of cities since it was more efficient.

The five mega-cities are representative metropolitan areas in Korea. They have repeatedly experienced centralizations of population, and had to enforce several government policies to decentralize population and develop suburban areas to accommodate immigrants.

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