# Remote Sensing the Urban Sprawl in South Korea: The Effects of Sprawl on Spatial Inequality

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***Abstract***

*South Korea has experienced rapid industrialisation and urbanisation over the past half century. While unbalanced population concentrations were already problematic, urban areas in South Korea continue to expand, causing a number of adjacent cities to merge into a continuous urban region. Previous studies found that rapid urban expansion and sprawl often lead to increased spatial inequality and social disparities. There have been many attempts to measure the degree of sprawl around the world. However, studies investigating the effects of sprawl on spatial inequality in Asia remain underdeveloped. This study is an attempt to measure urban sprawl in South Korea using remote sensing techniques and to analyse the effects of sprawl on spatial inequality, which are identifiable from measures of the living environment and the quality of life of local residents based on the structural equation model (SEM). The results show that urban sprawl in South Korea has adverse effects in terms of increased economic, social, and environmental inequality. The greater the sprawl, the greater the income inequality. Job quality, air quality, and residents' accessibility to social infrastructure also decline. Negative effects were also found in terms of the living environment and the quality of urban life in high sprawl areas.*

***Keywords:*** *Urban Sprawl, Spatial Inequality, Remote Sensing, Structural Equation Modelling*

## Introduction

The world has experienced rapid urbanisation since the Industrial Revolution, and 56% of the world's population live in urban areas as of 2020. UN (2019) predicts that this figure will increase to 68% by 2050, and that more than 90% of this growth will occur in Asia and Africa. The urbanisation experienced by emerging Asian countries, such as South Korea, China, India, and Vietnam, is occurring differently from the suburbanisation of Western countries. While Western suburbanisation involves a low-density propagation centred on suburban homes motivated by increased income, urbanisation in most emerging countries is characterised by high-density sprawl brought on by the drastic increase of the urban population. To generate rapid economic growth, most emerging countries have sought an imbalanced development of growth centres to concentrate resources on central cities, and rural populations have quickly gathered in urban areas in pursuit of jobs. Through this process, the unstable policies and urban planning systems of some countries have led to disordered and inefficient urban sprawl, causing political, economic, social, and environmental challenges.

Rapid urban expansion and sprawl often cause multidimensional spatial inequality and regional disparities (Wei and Ewing, 2018). For example, previous studies have shown that sprawl has negative economic effects, including an increased income gap, decreased job quality, and spatial separation due to the gap between the rich and the poor (Chapple, 2018; Guo *et al.*, 2019). The representative examples of these studies demonstrate the spatial mismatch hypothesis, which states that spatial separation leads to wage inequality (Gobillon *et al.*, 2007). From a social viewpoint, it has been confirmed that sprawl leads to inequalities in education, migration, and access to public services (Batchis, 2010; Ewing *et al.*, 2016a; Ewing *et al.*, 2016b; Frenkel and Israel, 2018; Zhao, 2013). These inequalities are more severe in societies with racial and gender inequalities (McLafferty and Preston, 1992). Sprawl has also been found to have negative environmental impacts, including the loss of urban open spaces, deterioration of air quality, destruction of ecological systems, and increased surface temperature (Bereitschaft and Debbage, 2013; Schweitzer and Zhou, 2010; Stone, 2008; Stone *et al.*, 2010).

South Korea is unique in accomplishing urbanisation due to the dramatic industrialisation and economic growth of the past half century. Urban growth has now passed the period of maturation, and a lower population growth rate and population decreases are predicted. However, indiscreet sprawl still continues in the Seoul Metropolitan Area. As young people continue to move into the Seoul Metropolitan Area for education and employment, it is expected that population decreases will accelerate outside of Seoul. Efforts have been made to measure the morphological and functional characteristics of sprawl in the context of the rapid urbanisation in emerging Asian countries, but spatial inequality resulting from sprawl has not been investigated sufficiently.

This study was conducted with two main purposes. First, the current degree of urban expansion and the level of sprawl in South Korea were measured using the urban remote sensing technique and the entropy index. Satellite-based remote sensing allows for quick and easy analysis of the time-series sprawl of extensive urban areas. In addition, the entropy index is employed to intuitively judge the distribution patterns of urbanised areas extracted from satellite images from the viewpoints of compression and dispersion, enabling easy measurement of the degree of sprawl. Second, a structural equation model (SEM) was used to analyse the effects of the urban sprawl in South Korea on spatial inequality and regional disparities as well as on the quality of life of the local residents who experience spatial inequality and regional disparities.

## Theoretical Background

### Urban Sprawl: Characteristics and Measurements

Scholars generally describe the characteristics of sprawl using the disordered planar expansion of urbanised areas or the spatial pattern of low-density development. For instance, Ewing (1994) summarised the characteristics of urban sprawl by describing inappropriate land use patterns, such as ‘scattered’, ‘leapfrog’, and ‘continuous low-density development’. Identifying the causes and results of sprawl has also been discussed. For example, privately-owned cars and communication technologies have caused the spatial expansion of urban areas (Brueckner, 2000; Ewing, 1994). Researchers argue that sprawl increases unnecessary social infrastructure, causes excessive transportation and confusion between urban areas and suburbs, and brings about other negative impacts such as health deterioration, energy waste, and air pollution (Ewing and Rong, 2008; Ewing *et al.*, 2003; Ewing, 1994; Lopez, 2004). On the other hand, some argue that traffic and air pollution occur rather in highly populated downtown areas, and that individual choice and equality should be considered (Gordon and Richardson, 2000). Additionally, lower levels of sprawl correspond to higher levels of financial well-being (Lee *et al.*, 2018).

Since the 2000s, efforts have been made to quantitatively measure urban sprawl. Spatial metrics focused on land use patterns in urban areas. In this type of study, a composite index is prepared and measured to explain the morphological aspects of sprawl, including the density, continuity, accessibility, polycentrality, clustering, and land use complexity of urbanised areas (Galster *et al.*, 2001; Huang *et al.*, 2007; Tsai, 2005). Spatial statistics, meanwhile, explain the functional aspects of sprawl using the measurements of various socioeconomic indexes, including population, employment, traffic, GDP, land use efficiency, and quality of life (Chenghuan *et al.*, 2001; Hasse, 2004; Torrens, 2008). The entropy index is another means of measuring the degree of urban sprawl based on remote sensing (Bhatta *et al.*, 2010a; Bhatta *et al.*, 2010b), allowing the researcher to intuitively judge the distribution patterns of an urbanised area from the viewpoints of compression and dispersion. Yeh and Li (2001) applied the entropy index to the Pearl River Delta in China, and Bhatta *et al.* (2010a) applied it to West Bengal in India.

### Urban Sprawl and Spatial Inequality

While several studies have focused on either urban sprawl or spatial inequality, few studies have focused on the correlations between them (Wei and Ewing, 2018). Generally, spatial inequality refers to the disparity between regions caused by the poor distribution of resources, services, or opportunities, which include inequalities of income, employment, education, migration, and access to public services. A spatially unequal distribution of resources, services, or opportunities may cause populations to be unnecessarily and unjustly deprived of opportunities. In addition, severe regional disparities bring about conflicts between regions, making it difficult to utilise resources appropriately. Furthermore, regional disparities may disrupt the stable development of a society by blocking social cohesion (Cho, 2011).

Spatial inequality may result from free market competition, but it also can be artificially created by the intervention of public policies. For example, scholars reported that spatial inequality is caused by the location selection of enterprises seeking maximum profit, as well as by households preferring quality jobs or living infrastructure. They also stated that spatial inequality is the final outcome of the balance between the forces of compression and dispersion under the geographical concentration of demand and limited land resources (Kim, 2008). Conversely, researchers focusing on the inequality caused by public policy interventions argue that a top-down development approach and policies encouraging imbalanced growth centres artificially increase regional disparities (Wei *et al.*, 2017). This is particularly true in developing countries, where rapid urbanisation and foreign investment, which tends to be concentrated on specific regions, are under the absolute control of governmental policies.

## Methodology

### Study Area

South Korea is one of the emerging Asian countries that have experienced rapid urbanisation over the past half century. With strong government support since the 1960s, export industries and the attraction of foreign investments have facilitated drastic economic growth and urbanisation. From the viewpoint of spatial inequality, however, the regional disparities and conflicts between the Seoul Metropolitan Area and outlying areas remain severe due to the development strategy based on imbalanced growth centres. In order to measure the degree of sprawl and spatial inequality, this study investigated 248 administrative districts (si, gun, and gu) of South Korea. Small islands of independent administrative districts were not included.

### Hypothesis and Conceptual Framework

Two hypotheses were established to experimentally investigate how the degree of urban sprawl in the context of South Korea's urbanisation related to multidimensional spatial inequality or regional disparities, and a conceptual framework to test the hypotheses was prepared using a structural equation model (SEM).

1. *Urban sprawl may negatively affect spatial inequality.* It has been known that urban sprawl has negative effects, shown most often by studies of Western countries. This study attempted to verify the significance of multidimensional relationships between sprawl and spatial inequality in the context of emerging Asian countries that have experienced rapid urbanisation, specifically South Korea. With reference to previous studies, the concept of spatial inequality was divided into 'economic', 'social', and 'environmental' aspects, prepared as latent variables for quantitative measurement through SEM.

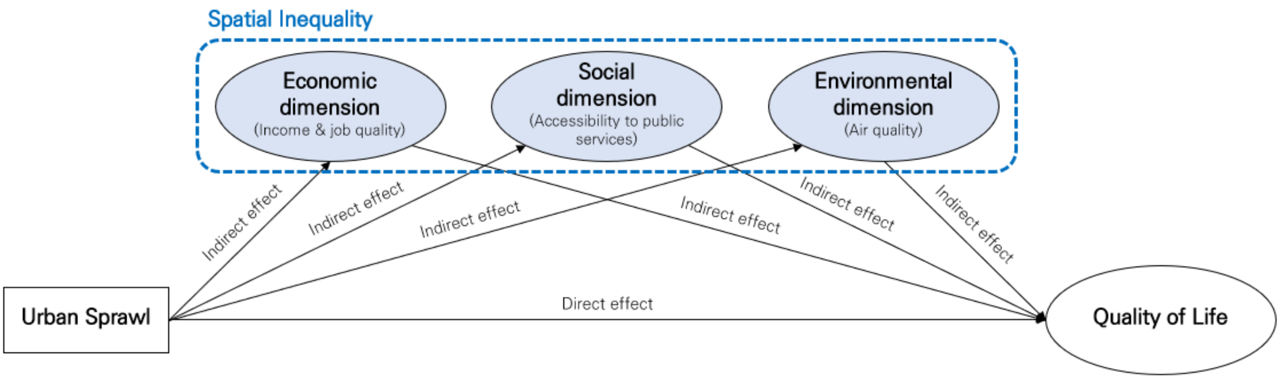


***Figure 1.*** *Conceptual framework*

2. *Urban sprawl, mediated by spatial inequality, may negatively affect the living environment of local residents and reduce their quality of life.* Lee *et al.* (2018)'s empirical study of American cities demonstrated a significant relationship between sprawl and well-being. The subjects who actually experience the spatial inequality, resulted from urban sprawl, are probably the local residents. Therefore, it was assumed that the local residents who live in areas with a higher degree of sprawl may experience more spatial inequality and regional disparities.

## Data and Methods

### *Measuring Urban Sprawl*

Urban sprawl was measured by remote sensing based on satellite images. This study used satellite image data from Landsat 8, provided by the United States Geological Survey. The 153 images, taken between March and October 2020, were composed after cloud masking. The urbanised areas were extracted from the images by supervised classification, a pixel-based land cover classification method. The land cover was categorised into four classes: urban, water, forest, and cropland. The urban class was used for sprawl measurement. Measurement of urban sprawl was performed using an entropy index that was applied the previous studies.

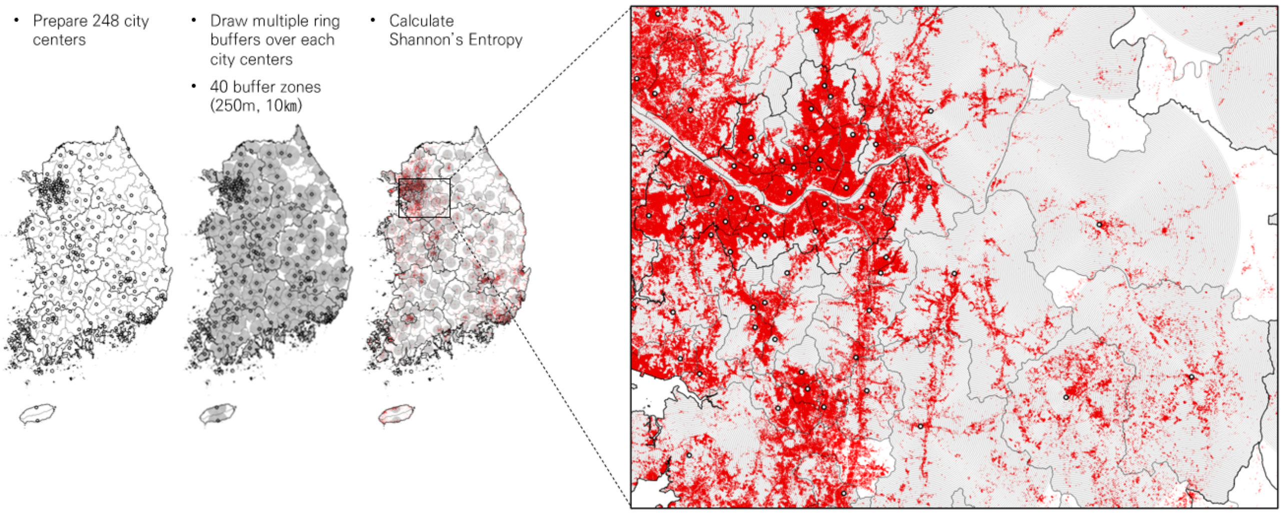


***Figure 2.*** *Measuring urban sprawl using entropy from the urban areas (Yeh and Li, 2001)*

### *Measuring Spatial Inequality and Quality of Life*

Spatial inequality and the quality of life were measured using indexes from the statistical data and relevant previous studies. The economic inequality indexes were the income Gini index, analysed by Hong *et al.* (2018), and the local job quality index, analysed by Lee (2019). Access to public services was used as the social inequality index, calculated for each administrative district using data from the National Geographic Information Institute. The environmental inequality index was prepared using data from South Korea's Ministry of the Environment on the emissions of eight major air pollutants (i.e., CO, NOx, SOx, TSP, PM10, PM2.5, VOC, and NH3). Finally, the quality of life index from the Local Community Health Survey, conducted by the Korean Disease Control and Prevention Agency, was used.

*Structural Equation Modelling (SEM)*

SEM is suitable for measuring the effects of sprawl and spatial inequality on quality of life because it can investigate the causal relationships between theoretical constructs. Because the concepts of spatial inequality and quality of life are difficult to measure directly, it is important to gather many indicators to best describe their significance and construct latent variables. Hence, an exploratory factor analysis (EFA) and a confirmatory factor analysis (CFA) were performed to determine the measurement variable that best described spatial inequality and quality of life among the variables. Next, a path analysis was performed to explain the causal relationships. The software program used for the analyses was the R-lavaan package.

## Results and Discussion

The highest level of urban sprawl in South Korea in 2020 was measured in Pyeongtaek-si in Gyeonggi Province, followed by Hwaseong-si in Gyeonggi Province and Gangseo-gu in Busan. The 10 most sprawling regions are mainly distributed on the outskirts of Seoul and Busan, where the population, economy, industry, and infrastructure are all concentrated. These are also hubs of unbalanced growth, encouraged in their sprawl by the government in the early stages of economic growth.

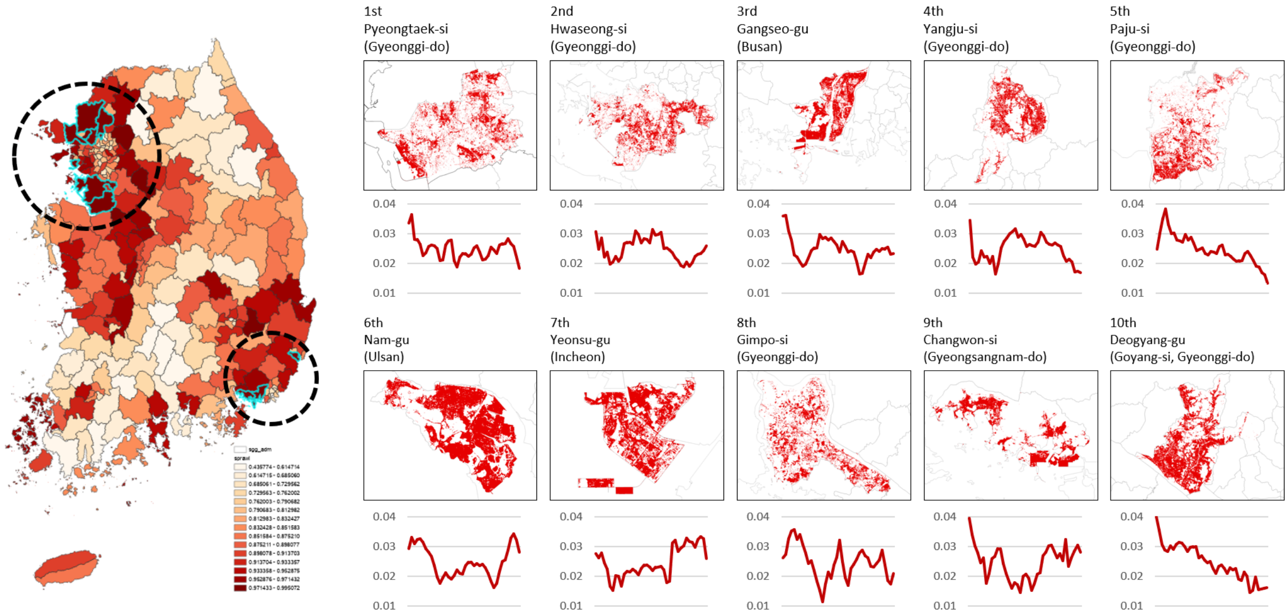


***Figure 3.*** *Degree of urban sprawl (x-axis: distance from the city centre, y-axis: entropy values)*

Analysis of the effects of sprawl on spatial inequality using SEM revealed statistically significant relationships: spatial inequalities in economic, social, and environmental dimensions are all positively correlated. In other words, greater sprawl is associated with greater economic income inequality and reduced job quality. In the social dimension, areas with greater sprawl enjoy greater physical access to public service facilities. In the environmental dimension, air pollution tends to increase in areas with greater sprawl. Furthermore, the level of sprawl and the resulting spatial inequality negatively affect quality of life.

**Table 1.** SEM result

| Paths | Std. Coeff. | Coeff. | Std.Error | z-value | P(>\|z\|) |
|---|---|---|---|---|---|
| ECONOMIC ← sprawl | 0.136 | 1.000 | 0.444 | 2.251 | 0.024 |
| SOCIAL ← sprawl | 0.443 | 7.563 | 0.979 | 7.728 | 0.000 |
| ENVIRONMENTAL ← sprawl | 0.535 | 3.468 | 0.352 | 9.849 | 0.000 |
| QOL ← sprawl | -0.149 | -12.154 | 4.971 | -2.445 | 0.014 |
| QOL ← ECONOMIC | -0.085 | -0.945 | 0.455 | -2.076 | 0.038 |
| QOL ← SOCIAL | -0.813 | -3.883 | 0.291 | -13.339 | 0.000 |
| QOL ← ENVIRONMENTAL | -0.219 | -2.763 | 0.706 | -3.912 | 0.000 |

However, some limitations recognised in the analysis will need to be addressed in future research. The first concerns the entropy index. Depending on the method applied by Yeh and Li (2001), comparing administrative districts of different sizes results in inaccurate comparisons. Small administrative districts tend to have relatively centralised development, potentially underestimating their sprawl. A sensitivity analysis will be needed in future studies. Second, modifying the SEM model is needed due to its insufficient fit. There may be a lack of sample numbers, a lack of multivariate normality of variables, a limit to measuring latent variables, or a lack of theoretical validity in the model itself. This problem will be corrected by adequately reviewing the variables and models.

## Conclusion

This study has attempted to use remote sensing and the entropy index to measure the urban sprawl caused by South Korea's rapid urbanisation over the past half century. The analysis confirmed that the level of sprawl was high on the outskirts of the Seoul Metropolitan Area and major coastal cities, which were extensively developed as unbalanced growth hubs. Analysis tentatively confirmed that sprawl has a negative effect on spatial inequality. It was also tentatively confirmed that greater sprawl correlates with lower resident satisfaction. Sprawl and inequality have been shown to be worse in outer population areas than in downtown areas, which suggests that new policies are needed to encourage spatial equality through more efficient urban management. Finally, this study is meaningful in that it conducted its analyses using not only the empirical measurement of sprawl but also the theory of spatial inequality.

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