# EXAMINING COMMUTING TIMES AND JOBS-HOUSING IMBALANCE IN SEOUL: AN EMPIRICAL ANALYSIS OF URBAN SPATIAL STRUCTURE

A Thesis

by

SUN MI JIN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF URBAN PLANNING

August 2012

Major Subject: Urban and Regional Planning

Examining Commuting Times and Jobs-housing Imbalance in Seoul: An Empirical Analysis of Urban Spatial Structure

# EXAMINING COMMUTING TIMES AND JOBS-HOUSING IMBALANCE IN SEOUL: AN EMPIRICAL ANALYSIS OF URBAN SPATIAL STRUCTURE

A Thesis

by

SUN MI JIN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF URBAN PLANNING

Approved by:

| | |
|---|---|
| Chair of Committee, | Kenneth Joh |
| Committee Members, | Douglas Wunneburger |
| | Xuemei Zhu |
| Head of Department, | Forster Ndubisi |

August 2012

Major Subject: Urban and Regional Planning

# ABSTRACT

Examining Commuting Times and Jobs-housing Imbalance in Seoul: An Empirical Analysis of Urban Spatial Structure. (August 2012)

Sun Mi Jin, B.E.; B.S., Kangnam University, Korea

Chair of Advisory Committee: Dr. Kenneth Joh

Public transportation policy plays a significant role in facilitating ridership as well as travel modes, economic activities, and environmental aspects. Seoul has experienced rapid urbanization. Also, high density developments and uncontrolled land use gave rise to extensive urban sprawl in the Seoul Metropolitan Areas (SMA). Due to increased use of private vehicles, which created serious traffic congestion, the Seoul Metropolitan Government (SMG) has reformed public transportation policies—introduced bus transportation reform (BTR) in 2004 and reformed fare and ticketing structures in 2009. This research focuses on the relationships between socioeconomic characteristics and commuting patterns by applying smart card data that includes individual travel behaviors during commuting periods. Among regression results, average commuting times are significantly associated with the proportion of population with lower levels of education and the number of public transit stations. These results appear to support the idea that the lower educated people in each district tend to have longer commuting times. Also, the greater availability of public transit stations contributes to shorter commuting times. Finally, analyzing commuting times seems to be

important for determining demographic movement as well as locational advantages in certain regions of Seoul based on public transportation policies.

# ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Kenneth Joh. This research would not have been possible without his support and guidance. Also, I would like to thank my committee members, Dr. Douglas Wunneburger and Dr. Xuemei Zhu, for their guidance throughout the course of this research.

Thanks also go to Dr. Shannon Van Zandt for her thoughtful consideration and Thena Morris for her great assistance at Texas A&M University. I also appreciate my advisor in Korea, Dr. Chun Ho Lee, for his encouragement and support of this research.

Finally, thanks to my parents and my sister for their encouragement and to my husband, Chang Ho Hur, for his patience, support, and love.

# TABLE OF CONTENTS

Page

# LIST OF FIGURES

# LIST OF TABLES

# 1. INTRODUCTION

Cities around the world are confronted with urbanization, which became a general phenomenon in the 20th century. Urbanization is determined by population concentrations in metropolitan areas (Henderson, 2002). The city of Seoul in Korea has become the epitome of the urbanization process due to rapid economic growth as well as changes in industrial structures in the past 30 years (Lee & Zang, 1998). Also, high density developments and unplanned land use gave rise to urban sprawl in the Seoul Metropolitan Areas (SMA) (Kwon, 2003). As a result, the SMA are faced with urban problems—environmental pollution, traffic congestion, lack of housing and infrastructure, as well as free-riding public facilities, which do not contribute to new developments due to unplanned revenues, and provide inadequate services shared with other communities (Cervero & Kang, 2011; Cho, 2005). The inner city of Seoul also suffers from high population density. Due to suburbanization, there is serious imbalance in jobs and housing, lack of public transportation, and congestion in the SMA. This is because the public transportation service is not provided evenly and people prefer to use private vehicles. As a result, traffic congestion gave rise to wastes of time and excessive energy consumption.

The purpose of this research is to analyze commuting patterns based on urban spatial structure and examine how well commuting patterns reflect the corresponding

---

This thesis follows the style of *Cities*.

patterns in the SMA. Recently, the Seoul metropolitan government (SMG) reformed its public transit policy to deal with these urban problems. Examining smart card data is a useful way to analyze relationships between urban form and commuting patterns. This research intends to examine the changes that occurred in Seoul after the reformation of the public transportation system and determine which variables influence commuting patterns in order to analyze the relationships between the urban form and commuting patterns.

Therefore, the objective of this research is to empirically examine the hypothesis of how individual commuting patterns vary using the public transportation data. It starts with a brief review of urbanization, describes the period of urban sprawl—commuting patterns and imbalance in jobs and housing—that occur in both the U.S. and Korea. In the same section, this paper focuses on reformed public transit policies in Korea to recognize the main features that influence public transportation and commuting patterns.

# 2. LITERATURE REVIEW

## 2.1 Urbanization in the U.S.

Urbanization is a consequence of urban development patterns (Henderson, 2002). That is, most cities have experienced urbanization if the cities have grown through the evolution of metropolitan areas. Also, developing countries commonly show a higher pace of urbanization compared to developed countries (Henderson, 2002). In many U.S. cities, urbanization has progressed from 40 percent to approximately 75 percent over almost a century (Henderson, 2002). Based on this process, about 64 percent of the people in the U.S. occupy urban regions (Larson, 1993).

Interestingly, an image of "Urban America" has been symbolized by these cities, such as New York, Chicago, and Los Angeles (Henderson, 1997), which represent traditional urban development in the U.S. After the Industrial Revolution, Chicago became one of the largest cities in the U.S. because essential elements, including a high ratio of immigrants, manufacturing companies, and transportation for urban growth concentrated in the central region of the city (Henderson, 1997; Levy, 2009). Accordingly, prosperity in economic activities and expansion of urban areas influenced urban structure during this period of Chicago history (Sohn, 2002). Chicago also took a longer period for the urbanization process in order to maintain the urban structure compared to Seoul.

*2.1.1 Urban Form and Commuting Patterns*

In the 1980s, the fast growth of metropolitan areas and suburbanization has been a natural evolutionary outcome of urban development. The natural evolution theory implies important roles for accessibility from residential areas to the central business district (CBD), affordable housing, and providing transportation (Mieszkowski & Mills, 1993). The reason is that all developments have dispersed to suburban regions due to a high concentration of people, limited economic activities, and lack of housing in urban areas. As a factor in alleviating density in urban areas, suburbanization can be considered a successful approach because of the serious congestion in the area of the CBD (Gordon, Kumar, & Richardson, 1989; Mieszkowski & Mills, 1993). However, employment decentralization in U.S. metropolitan regions caused variations in commuting patterns (Cervero & Wu, 1998).

In general, commuting patterns refer to journeys between home and workplaces (Aguiléra, Massot, & Proulhac, 2009; Dubin, 1991; Kim, Sang, Chun, & Lee, 2012; Sang, O'Kelly, & Kwan, 2011). Basically, the monocentric model considers the spatial separations of jobs and residential areas, which can be measured by commuting time and distance (Dubin, 1991). In daily travel activities, commuting patterns tend to be fixed schedules which are based on time and distance as opposed to others such as shopping and travel (Alexander, Dijst, & Ettema, 2010). Employees prefer to minimize commuting distance from home to work (Cervero & Wu, 1998). In addition, because the spatial distributions are related to individual housing and job locations, different commuting patterns develop in different areas (Kim et al., 2012). Among diverse arguments, Dubin (1991) concluded that commuting time would be a more appropriate measurement than distance in the monocentric cities because size and density are related to commuting time in employment centers. According to the monocentric model, all employment centers, which are defined by size and density, are developed in the CBD and housing values are higher there than outside of the CBD due to locational advantages (Dubin, 1991; Mieszkowski & Mills, 1993). To reach employment centers, long commuting trips are required because employees move from suburban areas (Giuliano & Small, 1993). People will commute long distances across the metropolitan areas as well as pay high commuting costs if they cannot compensate for housing values (Gordon et al., 1989; Mieszkowski & Mills, 1993). Because employment centers are mostly concentrated in metropolitan areas, the labor market in the CBD led to spatial segregation of jobs and residential areas (Matsuo, 2011).

To reduce density in the CBD, employment decentralization is considered to be a solution based on the monocentric model. Low density cities tend to have shorter commuting times because there are many chances for minimizing commuting time through changing locations—jobs and housing—and choosing different transit modes (Gordon, Richardson, & Jun, 1991). Gordon et al. (1989) agreed that high density gave rise to increased commuting time due to congestion in the CBD. Previous research has mentioned that population movement corresponds to job locations and employment decentralization tends to reduce commuting time and distance (Kim, 2008; Mieszkowski & Mills, 1993). That is, employees will have to travel less distance if firms will relocate outside of the CBD. The effect of employment decentralization refers to reducing high density in combination with short commuting time. Therefore, accessibility to jobs has an influence on urban spatial distribution, which can be supported by the monocentric model and is associated with urban economics theory.

Controversial issues in this area are that geographical scales and socioeconomic characteristics tend to impact commuting patterns (Kim, 2008). That is, it cannot be concluded that firm relocation is the only reason to have shorter commuting time. Dubin (1991) mentioned that dispersed workplaces might be influential in reducing commuting time, but it depends on socioeconomic characteristics. Cervero and Wu (1998) also have found that there is no clear relationship between dispersed jobs in urban spatial structure and shorter commuting distance. To analyze commuting flows, it is necessary to consider specific characteristics—occupation, gender, and census commuting data (Sang et al., 2011). This is because corresponding socioeconomic characteristics of commuters is based on urban spatial structure (Sohn, 2005). Also, Dubin (1991) pointed out that analyzing demographic characteristics and socioeconomic factors—income, occupation, mobility, and property values—play a significant role in determining commuting patterns. It can be concluded that commuting patterns depend on demographic characteristics that imply gender, race and ethnicity, and household responsibility (Lee & McDonald, 2003).

Among demographic characteristics, the gender gap is one of the more noticeable factors in determining the length of the journey to work. According to urban economic theory, an assumption is that commuting patterns will show similar trends under the same preferences and the same socioeconomic characteristics no matter the gender

(Johnston-Anumonwo, 1992; Zolnik, 2010). However, it seems to be questionable that the same commuting patterns can be found even with different characteristics that depend on gender. The influence of the gender gap on work trips has shown that women have shorter commuting times than men (Lee & McDonald, 2003; Madden, 1981; Sang et al., 2011; Zolnik, 2010). In contrast to the women's trips, long commuting patterns have some association with male commuting behaviors (Giuliano, 1998). The result supports the fact that gender disparity is a useful measurement for determining commuting time (Weinberger, 2007).

To support the gender differences on commuting time, a household responsibility hypothesis reported that women's roles tend to be more focused on household work or taking care of children than on occupation (Johnston-Anumonwo, 1992; Lee & McDonald, 2003). It can be implied that household responsibility impacts women's work trips. In several previous studies, the relationship between household responsibility and commuting patterns was investigated through diverse approaches, but the findings were inconsistent and the results are still controversial about whether or not household responsibilities result in shorter commuting time. Therefore, there is no clear evidence that short commuting patterns are associated with household responsibility or even the presence of children (Gordon et al., 1989; Johnston-Anumonwo, 1992). As a result, Sang et al. (2011) argued that the gender differences in commuting time and distance should be considered circumstances of locational factors—residences and workplaces—occupation, and income within cities.

Second, commuting patterns are associated with income or wages. Occupational status plays a crucial role in determining the length of commuting patterns (Sang et al., 2011). According to urban economic theory, low income commuters and women are associated with longer commutes because they may not be able compensate for the high costs of living near their employment. On the other hand, a person with a high income level is willing to pay more because the costs can be compensated for by shorter commuting time. Zolnik (2010) determined that income level of commuters heavily relies on time costs according to urban economic theory. Rosenbloom (2006) argued that low-wage workers are more often women than men. For these reasons, Madden (1981) concluded that women have very limited choices in job locations and prefer to work closer to their homes in spite of the low wages to avoid high commuting costs. This supports the idea that the gender gap in commuting patterns is associated with women's circumstances in employ status.

Commuting patterns are associated with locational factors—residences and workplaces—demographic characteristics, and socioeconomic characteristics. Also, commuting patterns contribute to travel demand forecasting, which regulates traffic congestions during peak periods—the morning commute time and evening rush hours—in the urban structure as well as improves air quality (Joh, 2009; Matsuo, 2011). Therefore, understanding urban spatial structure and decentralization should follow an analysis of the distribution of employment, population, housing demands, and transportation (Mieszkowski & Mills, 1993).

*2.1.2 Imbalance in Jobs and Housing*

Commuting patterns have become a significant indicator for analyzing the locations of jobs and housing based on the urban spatial structure (Sohn, 2005). Commuting trips estimate accessibility, which is measured by commuting distance and time to estimate the entire commutes to workplaces (Ma & Banister, 2006; Zhao, Lu, & Linden, 2009). Accessibility to jobs is a serious issue in growing metropolitan areas. As the spread of urban sprawl in cities grows, the issue being examined is imbalance in jobs and housing locations in the urban spatial structure (Giuliano & Small, 1993). Because suburbanization is connected with auto-dependence, air pollution, and traffic congestion (Bagley & Mokhtarian, 2002; Matsuo, 2011), long commuting distances are caused by geographical mismatches between residential locations and employment centers (Giuliano & Small, 1993). As a result, people tend to waste time in commuting long distances on highways due to urban sprawl. In particular, long commuting distances tend to encourage private vehicle use.

As sub-employment centers have rapidly grown in suburban areas, housing prices are highly correlated with commuting patterns. The imbalance is determined by a fundamental tradeoff between property values and commuting costs in choosing residential locations (Giuliano & Small, 1993; Ma & Banister, 2006). Choosing residential and workplace locations are limited depending on income level. The reason is that time and distance are correlated with cost (Giuliano & Small, 1993). Longer commuting distances will give rise to higher commuting costs due to the lack of accessibility between jobs and residences. On the other hand, residential property values tend to increase within public transit impact areas (Bae, Jun, & Park, 2003). High accessibility to public transits would increase housing prices, but make it possible to reduce travel time and distance. Accordingly, the work commuting behaviors of low income households are impacted due to residential location choice limitations (Ma & Banister, 2006). Therefore, this research assumes that the influencing factors of commuting are income, private vehicle availability, commuting time, commuting costs, accessibility of public transit, jobs, and housing locations.

### 2.2 Urbanization in Korea: Case Study of Seoul

Seoul, the capital city of South Korea, has experienced rapid urbanization since the 1950s. Unlike many U.S. cities, which had a long and steady urban development period, the most significant developments and rapid growth have occurred in Seoul after the 1960s (Sohn, 2005). Rapid urbanization, which is defined by rapidly growing industrial sectors and high concentrations of population in urban areas, has led to a remarkable transformation of population density and economic growth in Seoul (Kim & Mills, 1988; Rii & Ahn, 2001). Economic growth in Seoul has promoted the migration of populations from rural areas to Seoul due to job opportunities based on the transformation of the socioeconomic structure (Rii & Ahn, 2001). This phenomenon also implied that the movement of people led to the advantages of a central city life of political power, education, and social and cultural activities available in Seoul (Cervero & Kang, 2009; Lee, Lee, & Lee, 2006). However, many urban problems—urban sprawl, lack of public infrastructures, traffic congestion, and destruction of the environment—

have been caused by a high population density in Seoul. Although the Korean government recognized that the high density was associated with these urban problems, there was no policy to mitigate the side effects of urbanization until the late 1960s (Cho, 2002).

To regulate rapid urban growth and expansion in the SMA, the SMG adopted a greenbelts policy in 1971, which was established to prevent urban sprawl and preserve the natural environment (Cho, 2002; Jun & Hur, 2001; Kim & Mills, 1988; Rii & Ahn, 2001). Basically, this policy was put in place to regulate urban sprawl by implementing development regulations in suburban areas (Badamdorj, 2004). The greenbelts policy seemed to control the growth of the Seoul region and contribute to the preservation of open spaces on the outskirts of Seoul (Cho, 2002). Based on this policy, the Korean government expected to limit the extensive growth of its urban areas. However, disorderly leap-frog developments have spread to peripheral areas beyond the greenbelts regions. This discontinuous development is associated with growing satellite cities around Seoul (Rii & Ahn, 2001). As a result, the greenbelts policy failed to maintain continuous development in both the urban area and beyond the greenbelts boundaries (Cho, 2002). Due to the limitations of urban development in the adjacent areas of Seoul, the policy gave rise to serious problems of land shortages and lack of affordable housing in Seoul.

Land shortage is one of the negative outcomes of the greenbelts policy. Seoul has 25 districts under local government which are called *Gu* and 424 neighborhoods belonging to the districts and are called *Dong* (Jun & Ha, 2002). The majority of the 25 districts in Seoul are urbanized. Land expansion beyond the greenbelts regions is not allowed without government permission and the urban core is higher dense than the outer greenbelts areas (Rii & Ahn, 2001). The reason is that the inner city is surrounded by the greenbelts boundaries which are 10 kilometers in width and are at a distance of about 15 kilometers from the center of Seoul (Kim & Mills, 1988). In 2010, 10 million residents lived in Seoul, which is 20 percent of the total population of South Korea. The population density was 16,189 persons per $km^2$ in 2010. Considering the land area between Seoul and the SMA, the population density in Seoul is extremely high and is the most compact city in South Korea. In other words, providing available land for development is difficult without a policy change because Seoul's boundary is limited by the greenbelts regions. Because of this, the greenbelts policy can be identified as one of the reasons why the population density has increased in Seoul (Badamdorj, 2004).

Second, the supply of affordable housing is very limited in Seoul due to the high population density (Kim & Han, 2012). As mentioned earlier, rapid urbanization has encouraged a massive influx of migrants into Seoul, which created an imbalance between strong demand and insufficient supply. One of the issues in the Korean housing market is that residents are confronted with high property costs. Residential opportunities are very limited in Seoul because the property values have increased closer to the CBD and there is a greater accessibility to public transportation in Seoul (Cervero & Kang, 2011). Also, the housing prices are mainly associated with high land values. Land prices are expected to increase when agricultural land areas are converted to urban use in the future (Capozza & Helsley, 1989). The high demand and land use regulations of residential developments also contributed to increased land values (Kim & Han, 2012). Due to the limited housing, people who invest in the housing market are able to get high interest rates (Kim & Mills, 1988). These are still considered critical issues in the Korean housing market. As a result, expensive dwelling values, lack of public services, pollution, and congestion are beginning to be considered serious problems in the housing market.

As an alternative plan, the Korean government established new town development projects in the 1980s which are comprehensive approaches for providing affordable housing in the SMA. Basically, the purposes of the projects are decentralization of population and moving industries and their employees to the SMA (Rii & Ahn, 2001). According to the population trends through 2010, the total population in Seoul has declined slightly since the 1990s (Table 1). On other hand, the population trends in the SMA show that population growth has steadily increased since the 1990s. It can be assumed that people are relocating to the peripheral areas of Seoul because of the projects which alleviate the housing shortage and improve the residential environment.

Providing sufficient urban infrastructure and the condition of the infrastructure play a significant role in new town developments (Rii & Ahn, 2001). However, outmigration to the peripheral regions of Seoul is complicated by a lack of urban infrastructures and poor public services (Kim & Han, 2012). First, transportation needs have rapidly increased as a result of the rapid growth of the population in the SMA. Ironically, the project led to increased use of private vehicles due to

**Table 1**
Population Growth in Seoul and the Seoul Metropolitan Area (SMA).

| Year | National population | Population in Seoul | % | Population in the SMA | % |
|---|---|---|---|---|---|
| 1980 | 37,436,315 | 8,364,379 | 22 | - | - |
| 1985 | 40,448,486 | 9,639,110 | 24 | 15,820,156 | 39 |
| 1990 | 43,410,899 | 10,612,577 | 24 | 18,586,128 | 43 |
| 1995 | 44,608,726 | 10,231,217 | 23 | 20,189,146 | 45 |
| 2000 | 46,136,101 | 9,895,217 | 21 | 21,354,490 | 46 |
| 2005 | 47,278,951 | 9,820,171 | 21 | 22,766,850 | 48 |
| 2010 | 48,580,293 | 9,794,304 | 20 | 23,836,272 | 49 |

decentralization. The reason is that the projects are more focused on reducing population density than providing urban infrastructure in the SMA. Although the total population has declined since the 1990s, the demand for private vehicle ownership has increased to the point that there were 2.9 people per vehicle in 2008, which had quickly decreased from 4.0 people per vehicle in 2000. It can be concluded that the new town development projects led to the high private vehicle usage in the SMA. Accordingly, high demands for private vehicles gave rise to serious traffic congestion (Lee et al., 2006; Pucher, Park, & Kim, 2005). The average travel speed by passenger car in the central region was 17 km/h in 2010, which is slower than suburban areas at 24.5 km/h. That is, increasing the total number of vehicles led to severe traffic congestion in Seoul. These trends have caused decline in travel speeds by public transit as well, which led to inefficient services. As a result, insufficient transportation infrastructure and traffic congestion gave rise to long commuting time and high commuting costs (Rii & Ahn, 2001).

*2.2.1 Urban Form and Commuting Patterns*

In Korea, urban sprawl is defined as a disorderly arrangement of unplanned residential, industrial, and commercial developments beyond the greenbelts regions (Cho, 2005). Urban sprawl has resulted in the extensive SMA that has included Seoul, Gyunggi Province, and the city of Incheon (Lee & Lee, 2005). Bae et al. (2008) mentioned that the extensive SMA is associated with rapid new town developments and concentrations of employment centers. It can be concluded that the extensive SMA, which contained 49 percent of the total population in 2010, was negatively impacted by the greenbelts policy. As mentioned earlier, the greenbelts policy has promoted rapid urbanization that resulted in a lack of developmental land area in Seoul (Ha, 2010). Also, the population redistribution process in the SMA, which led to traffic congestion, lack of public infrastructure, and high property values, failed to estimate the public infrastructure capacity due to leap-frog developments (Cho, 2005). As a result, lack of public transportation facilities and traffic congestion has resulted in long commuting times and high commuting costs (Rii & Ahn, 2001). Consequently, this unplanned development form is related to changes in commuting patterns.

Understanding the interaction between commuting patterns and urban spatial structure plays a key role in the dispersion of employment. In general, commuting patterns are reflected locational factors that include labor force and residence (Kim et al., 2012). Theoretically, the monocentric model implies that employment decentralization will decrease commuting patterns if the locations of both residences and firm correspond to each other (Dubin, 1991). In other words, it indicates long commuting patterns if residences and firms are not related to these locations. Gordon et al. (1989) mentioned one of the problems in the monocentric city which is worsening traffic congestion closer to the CBD.

To support the belief that the spatial transformation in Seoul, unlike in U.S. cities, Jun and Ha (2002) argued that, since 1981, Seoul has transformed into a polycentric urban structure from a monocentric city. The polycentric city has clustered locations in both residence and employment centers in the metropolitan region and usually has the shortest commuting patterns (Gordon et al., 1989). Conditions of the employment centers are defined by high density and high quantity of employment (Jun & Ha, 2002). Seoul has a major CBD and two sub-centers—Youngdungpo and Kangnam—which have become even wider regions with higher densities since 1981 (Jun & Ha, 2002; Lee & McDonald, 2003). The two sub-centers marked the formative stage toward transformation to a polycentric city. In contrast to Jun and Ha, Sohn (2005) believed that Seoul is ideally suited to the monocentric model because the CBD in Seoul still retains dominance in many functions, which are strongly centralized by the controlling Korean government policies.

Since the 1980s, concentration and dispersion have existed in the SMA no matter what the urban spatial structure—monocentric or polycentric. A major objective of the new town development, which mitigates housing shortages, conflicted with preventing urban sprawl under the greenbelts policy. Jun and Hur (2001) pointed out that these two land use policies are a fundamental causation for shaping the leap-frog new town developments in the SMA. Moreover, land use patterns will influence commuting patterns (Giuliano & Small, 1993). Ideally, new town development is strongly connected with the CBD and it will provide a balance between population and employment (Jun & Hur, 2001). In other words, the new town regions will be self-contained even though the new towns are still linked to core cities.

However, dispersion of the population that contributed to the long commuting patterns and employment centers are not noticeable in the SMA (Jun & Ha, 2002). Employment centers were not effectively distributed in the SMA and this promotes long commuting patterns. Firms seem unwilling to relocate in the SMA due to the economic benefits of spatial clustering in Seoul (Jun & Hur, 2001). Moreover, Cervero and Wu (1998), based on urban economic theory, found that employment decentralization was not associated with reducing commuting patterns in rapidly growing areas. As mentioned earlier, Seoul is one of the most rapidly growing cities in the world (Jun & Ha, 2002). Employment decentralization has contributed to worse commuting patterns because of the geographical characteristics of Korea and development limitation through the greenbelts policy (Jun & Bae, 2000). Jun and Ha (2002) discovered that commuting distances became longer over the 1990-1996 period and even average commuting distances of new town residents to non-Seoul and non-center destinations were greatly increased among other regions over the 1990-1996 period, rising 8.78 km to 11.91 km and 7.98 km to 10.18 km, respectively. These results indicated that the new town development in the SMA led to longer commuting patterns and higher commuting costs (Jun & Ha, 2002; Jun & Hur, 2001).

The influence of gender differences also plays a significant role in commuting patterns. As mentioned earlier, some studies concluded that women have shorter work trips than men (Gordon et al., 1989; Lee & McDonald, 2003; Madden, 1981; Sang et al., 2011; Zolnik, 2010). The household responsibility hypothesis implies that women tend to be more focused on household work or taking care of children than occupational status, which becomes a secondary role (Johnston-Anumonwo, 1992; Lee & McDonald, 2003; Turner & Niemeier, 1977). In contrast to this hypothesis, other studies found that there is no supportive evidence that short commuting patterns are associated with household responsibility or even the presence of children (Gordon et al., 1989; Johnston-Anumonwo, 1992). Unlike in U.S. cities, household responsibility impacts women's work trips due to cultural differences in Korea. Regarding the cultural aspects in Korea, Lee and McDonald (2003) argued that the primary household responsibility falls on women and they are expected to take care of children and the presence of children is a significantly negative impact on women's short commute patterns, which is consistent with what Madden (1981) had concluded. A crucial reason is that many families still live with their parents or parents-in-law in Korea and parents can help with childcare, which is regarded as a burden on married women. As a result, women are willing to have short commuting patterns due to limitations in selecting workplaces.

Income segregation is another issue in commuting patterns. Commuting patterns based on the journey to work influence the decision where to live and work. Levinson (1997) argued that commuting patterns are a tradeoff between time and money. Sang et al. (2011) mentioned that job-related status is significant in determining the length of a commute. The length of commuting patterns may not significantly impact higher income households because considering commuting costs is not a tradeoff against property values (Gordon et al., 1989). However, low income commuters and women are associated with longer commutes according to urban economic theory (Weinberger, 2007; Zolnik, 2010). Since employment dispersion in the SMA, new town residents should be across the CBD and commuting time becomes longer because the expensive housing costs in Seoul are not compensated for by shorter commutes. The reason is that high accessibility to employment centers produces the highest housing costs (Levinson, 1997). That is, workers prefer to obtain housing benefits in the SMA instead of reducing commuting costs. This implies that suburbanization of employment centers and housing leads to increased commuting patterns across the CBD (Levinson, 1997). As a result, commuting patterns tend to be related to wages so that the imbalance between jobs and housing has become a critical issue in the SMA.

### *2.2.2. Imbalance in Jobs and Housing*

Excessive commuting is determined by distances and time that indicates an imbalance in jobs and housing (Suzuki & Lee, 2012). Long commuting patterns are measured by locational mismatches between employment centers and residences (Ma & Banister, 2006). Theoretically, minimum commuting is the minimum distances or time that workers move from homes to employment centers (Layman & Horner, 2010). However, Giuliano and Small (1993) found that short commuting patterns are not correlated with the balance in jobs and housing because commuting patterns heavily rely on social factors—distribution of minority groups and the location of neighborhoods.

In the case of Korea, the two land use policies—the greenbelts and new town developments—resulted in long commuting patterns and locational imbalance between jobs and housing units in the SMA. These policies led to housing shortages and limited residential land available in Seoul. The imbalance caused a tradeoff between property values and commuting costs in choosing residential locations (Giuliano & Small, 1993; Ma & Banister, 2006). Unlike in U.S. cities, because sub-employment centers have rapidly grown and are still located in Seoul, housing prices are highly correlated with commuting patterns. Construction of high-rise apartments, which are the most common type of homes in Korea, was undertaken to mitigate the lack of housing in the SMA (Ha, 2010). However, property values seem to increase closer to the CBD so that long commuting patterns led to higher commuting costs due to the lack of accessibility between employment centers and residences. As a result, a spatial imbalance arises in that workers who live near their workplaces find it beyond their ability to pay housing costs so that housing costs mainly reflect commuting patterns (Giuliano & Small, 1993). This implies that accessibility is a determining factor in maintaining balance between jobs and housing (Ma & Banister, 2006; Zhao et al., 2009) so that the accessibility impacts how residential and employment locations are chosen and how individual commuting patterns are decided.

Therefore, examining the jobs-housing imbalance is important in explaining commuting patterns, which are related to the reduction of traffic congestion and air pollution (Ma & Banister, 2006). Murphy (2009) concluded that using public transportation will reduce commuting time based on high accessibility to the public transportation network for transit riders. Since Korea has formed a centralization of employment in the urban spatial structure, spatial disparities between residences and workplaces became noticeable problems. To solve these complicated problems in the SMA, the SMG suggested that a reformation of public transit policy will mitigate inconvenience in using the public transportation system and minimize the side effects of the greenbelt policy.

### 2.3 Introducing New Public Transit Policies

Focusing on automobile usage, the SMG has recognized that improving public transportation policies plays a significant role in relieving the demand of private vehicle ownership and restoring the high quality of public transportation services in the SMA (Cervero & Kang, 2011; Lee et al., 2006; Pucher et al., 2005). Some of these policies have included introducing bus transportation reform (BTR) in 2004 and reformed fare and ticketing structures in 2009. After introducing these public transportation policies, the SMG expected improvements in the road traffic environment such as increased travel speeds, reduced travel time, and improved travel routes and modes (Cervero & Kang, 2011).

Before introducing new public transportation policies, reformed bus fares and service structures, one of the problems was that a number of transit companies faced financial difficulties because only 75 percent of operating costs were covered by passenger fares (Pucher et al., 2005). This became a financial burden to the SMG with limited revenue. Another issue was that many companies suffered from excessive competition, which led to offers of redundant service routes as well as a lack of schedule coordination within the same routes by different companies (Pucher et al., 2005). This gave rise to insufficient service frequency and decreased ridership. Because of these issues, the public transportation system did not have an attractive image. The current quality of service does nothing to increase public transit ridership. Regarding public transportation problems in Seoul, integrating land use planning and public transit policy would be helpful in mitigating the public transportation problems (Van Acker & Witlox, 2011). As a result, these issues motivated the SMG to review the public transit system.

### *2.3.1 Introducing a Median Bus Lane System*

To improve travel speed, the SMG adopted a median-lanes bus system, in which only buses operate in the newly constructed median lanes. Early in the implementation of the policy, it was found that bus lanes are not an effective way to resolve the problem due to safety issues and impeding bus movements (Kim, Cheon, & Lim, 2011). Because of the location of the bus station, which is in the median of the roads, it seemed unsafe when people were boarding or waiting for the bus in the space. However, bus travel speeds have increased to approximately 20 km/h after the introduction of the median-lanes bus service. Since 2007, the bus travel speeds remained stable at about 20km/h, which is a positive result of the median-lanes bus system. In 2010, a total distance of 107. 2 km of bus only lanes was offered in Seoul, and is based on extensions newly built since 2004. At the same time, there are other attempts to reduce congestion such as changing the traffic signal systems for buses, coordinating bus schedules based on the bus management system (BMS), and improving bus stop facilities (Cervero & Kang, 2011). These efforts save travel time and should increase public transit ridership.

### *2.3.2. Reforming Fare and Ticketing Structure*

The SMG has introduced new fare structures and bus services, in which the functions are identified by four colors—green, blue, red, and yellow—and service routes have been changed (Cervero & Kang, 2011). Each color represents a different type of service: feeder service is green, trunk service is blue, long distance service is red, and circulation service is yellow (Table 2). Two bus services—feeder and trunk—play a significant role in providing public transit service between bus and subway in Seoul. The connection contributes to increased accessibility in every region. In 2011, 66 Seoul bus companies were authorized by the SMG to offer 366 service routes using 6,644 vehicles (Table 2).

**Table 2**
Operating Bus Conditions in Seoul.

| Types of buses | Companies | Lines | Color | Permitted vehicles | Actual operating vehicles |
|---|---|---|---|---|---|
| Feeder | 56 | 119 | Green | 3,698 | 3,271 |
| Trunk | 59 | 228 | Blue | 3,527 | 3,103 |
| Long distance | 6 | 13 | Red | 275 | 240 |
| Circular | 3 | 6 | Yellow | 34 | 30 |
| Total | 66 | 366 | - | 7,534 | 6,644 |

The overall fare structure is defined by total travel distance and an additional fare is charged for each 5 km after an initial 10 km. The fare collection system for both the bus and subway has been through a smart card since 2009. Accordingly, the fare structure includes transfers, which guarantees free boarding within 30 minutes or an automatically discounted second boarding no matter what type of public transportation the rider has transferred from (Kim et al., 2011). The SMG has integrated all public transit fare structures into an initial travel distance parameter of 10 km. Due to the introduction of the smart card as T-money, it is possible to estimate actual travel time and distance.

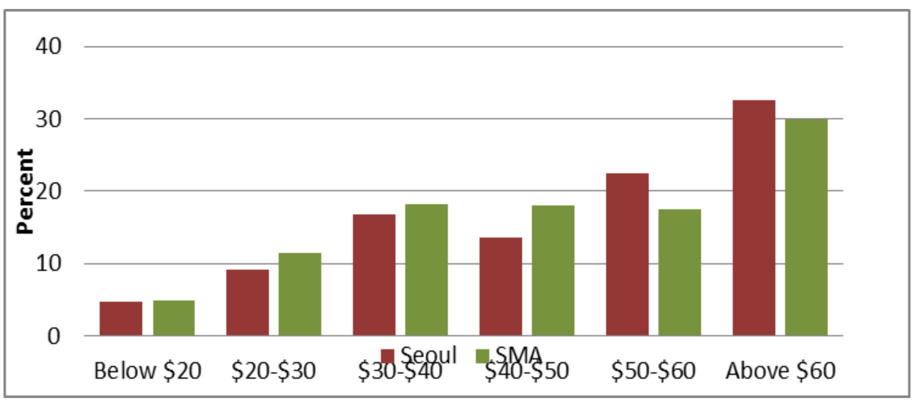



**Fig. 1.** Monthly Public Transit Fares in Seoul and the Seoul Metropolitan Areas (SMA).

Fig. 1, which compares the monthly fares for Seoul and the SMA, shows that more than 50 percent of riders spent over $60 per month for public transportation in 2007. Therefore, the new fare structure became widely used by passengers because it was an efficient way to save public transit costs, carrying the smart card was more convenient than carrying cash, and boarding times were reduced. The next two sections provide further details on the data and methodology.

# 3. DATA AND METHODOLOGY

## 3.1 Data: Smart Card Data

Smart card is an integrated transit fare card system which encourages ridership as well as provides passenger convenience. Table 3 shows the detailed information contained on the smart card—card ID, transfer frequency, boarding time and location, alighting time and location, and transit fares based on the integrated transit fare card system, called T-money system in Korea. The T-money system is an advanced method to collect transit fare and trip records in Seoul, which corresponds to the reform of public transit policies (Kim & Kang, 2005). The method has become a popular payment system because of its efficiency and savings in travel costs (Jang, 2010). Also, the smart card system plays a significant role in the improvement of public transportation for several reasons: reducing on-board fare collection time, a convenient method for carrying, and easily calculating additional fares when transferring to other travel modes (Giuliano, Moore II, & Golob, 2000). The smart card system automatically collects individual passenger trip information for a single day, which is used to estimate travel behaviors (Lee, Jung, Park, & Choi, 2008).

To analyze commuter trips, the smart card data is a useful method in that the recorded information is associated with one person's travel history during a single day. Due to the difficulty of gathering data, one advantage of using the smart card is that it provides specific information used to estimate locations and waiting times between travel modes in public transportation. Moreover, differentiations between origins and

**Table 3**
Descriptions of the Smart Card Data in 2010.

| | Variables | Descriptions |
|---|---|---|
| 1 | Card ID | Card number of each smart card |
| 2 | Origin time | Boarding time |
| 3 | Transaction ID | Identification for transfer |
| 4 | Type mode | Bus and metro |
| 5 | Transfer frequency | Number of transfers |
| 6 | Bus line ID | Identification for bus and metro |
| 7 | Bus ID | Bus vehicle ID |
| 9 | User classification | Type of user |
| 10 | Boarding station ID | Origin location of bus and metro station |
| 11 | Alighting time | Arrival time |
| 12 | Alighting station ID | Destination location of bus and metro stations |
| 13 | Number of passengers | Number of persons paid for by the card |
| 14 | Basic fare | Initial fare when boarding |
| 15 | Additional fare | Additional paid fare when arriving |

destinations are able to be seen in an individual's travel patterns according to the data (Layman & Horner, 2010). Because long transfer waiting times during peak hours are caused by several reasons such as traffic congestion and lack of public transportation service frequency, it is a useful method for regulating the public transportation system. The data is also a useful way to understand travel behaviors. People prefer to use optimized routes among possible routes to reduce wasted time. Travel behaviors heavily rely on short term decisions, the number of trips, and travel time duration, rather than long term decisions (Silva & Goulias, 2009). Travel behaviors are also related to personal preferences which are involved in socioeconomic characteristics based on time and distance.

### 3.2 Methodology: Stratified Sampling and Multiple Regression Models

This research applied to smart card data in 2010, which was collected and distributed by the SMG. The gathered data fully considered the total number of public transit trip records on Monday, February 22 in 2010. Alexander et al. (2010) found that evening commuting patterns were more varied than morning commutes. Therefore, morning commutes were used in an effort to obtain more consistent results. To ensure adequate sample sizes during the morning commutes in Seoul in this research, two conditions are established that the time intervals were between 6 a.m. to 9 a.m. and the trip originated in Seoul. Among all recorded trips within the SMA, 1,534,636 of the total number of public transit commute trips met the two conditions.

In order to produce more accurate estimations in this research, it is necessary to employ stratified sampling based on a proportional allocation of the total observations to different strata. The reason is that Seoul has 25 districts and there may be differences in commuting patterns among the 25 districts. Allocation of sample sizes should be different and reflect the diverse characteristics among the 25 districts. The stratified sampling that is separately employed within each district is more appropriate for improving estimations for each stratum independently. To examine commuting time, the stratified sampling was necessary to allocate sample sizes based on the proportion of the total trip observations across the 25 districts. The sample sizes ranged from 261 to 946, with a mean sample size of 614. Average commuting times for each district were calculated by aggregating the commuting times for the sampled observations and dividing by the sample size, shown in Table 4.

Many studies more often examined commuting distances, which were measured by network analysis and Euclidian distance analysis using Geographical Information Systems (GIS). The distance length of a commute in each district can be shown to illustrate district has longer commuting distances than others. The reason that commuting time is relatively harder to estimate than commuting distance is because of a lack of data availability. Unlike previous studies looking at commuting distances, this research focused on examining average commuting times in the 25 districts and the commuting times would fully represent the characteristics of travel behaviors.

By applying the data, population movements and concentrated locations in Seoul, which indicate employment centers or activity centers, can be determined. This is supported by analyzing the smart card data which contains commuting times and socioeconomic variables—characterized by the number of businesses, population with lower levels of education, the number of transit stations, density, and car ownership. Therefore, analyzing the smart card data helps to identify daily trip patterns and the present urban spatial structure in Seoul.

In this research, a multiple regression model is used to examine the relationships between commuting time and socioeconomic variables. The multiple regression analysis identifies associations between response variable $Y$ and multiple explanatory variables $X$.

**Table 4**
Average Commuting Times of the 25 Districts (Gu) in Seoul.

| Districts | Sample sizes | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Gangnam-gu | 919 | 19.75025 | 16.83702 | 2.01667 | 163.95 |
| Kangdong-gu | 526 | 34.29718 | 20.01424 | 2.3 | 203.833 |
| Gangbuk-gu | 549 | 29.53106 | 20.83137 | 2.16667 | 144.3 |
| Gangseo-gu | 790 | 31.42698 | 20.80879 | 2.13333 | 129.167 |
| Gwanak-gu | 919 | 24.905 | 17.84155 | 2.03333 | 280.667 |
| Gwangjin-gu | 639 | 24.55269 | 15.05737 | 2.33333 | 91.8333 |
| Guro-gu | 901 | 29.88324 | 17.73493 | 2.01667 | 137.133 |
| Geumcheon-gu | 261 | 24.90702 | 19.07506 | 2.1 | 136.433 |
| Nowon-gu | 876 | 34.3933 | 20.30291 | 2.03333 | 135.6 |
| Dobong-gu | 479 | 35.94308 | 21.99565 | 2.08333 | 143.117 |
| Dongdaemun-gu | 513 | 24.02388 | 20.18076 | 2.05 | 257.383 |
| Dongjak-gu | 832 | 23.45198 | 13.9162 | 2.18333 | 135.417 |
| Mapo-gu | 589 | 26.0807 | 17.06767 | 2.08333 | 148.4 |
| Seodaemum-gu | 340 | 21.77191 | 16.45684 | 2 | 78.2167 |
| Seocho-gu | 614 | 16.97128 | 13.43257 | 2 | 77.9833 |
| Seongdong-gu | 511 | 24.34595 | 15.26264 | 2.31667 | 107.933 |
| Seongbuk-gu | 687 | 24.51793 | 17.24304 | 2 | 123.883 |
| Songpa-gu | 946 | 22.88053 | 17.11387 | 2.01667 | 95.65 |
| Yangcheon-gu | 472 | 25.74615 | 19.68732 | 2.06667 | 128.083 |
| Yeongdeunpo-gu | 656 | 23.25127 | 16.68128 | 2.06667 | 164.233 |
| Yongsan-gu | 340 | 18.9402 | 16.61668 | 2 | 156.433 |
| Eunpyeong-gu | 748 | 29.18026 | 19.68383 | 2.1 | 130.933 |
| Jongro-gu | 360 | 19.50889 | 15.69566 | 2.13333 | 111.717 |
| Jung-gu | 331 | 22.46863 | 18.2235 | 2.13333 | 165.783 |
| Jungnang-gu | 550 | 28.46961 | 21.68721 | 2.01667 | 271.383 |
| Total sample sizes | 15,346 | - | - | - | - |
| Mean across all districts | 614 | 25.64796 | - | - | - |

The multiple regression models are represented by the following equation. In this equation, x represents independent variables, y is the dependent variable, and *k* is the observation.

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + \cdots\cdots + b_kX_k + e \qquad (k=1, 2,\ldots, n) \qquad (1)$$

To analyze commuting time using the smart card data, the multiple regression models support the idea of spatial variations in jobs and housing differences in commuting patterns. Many studies indicate that commuting patterns are associated with multiple factors such as locations—housing and employment centers—and public transportation availability. Table 5 presents variables for analyzing associations between commuting times and socioeconomic variables. The dependent variable is the average commuting time in each district and five types of independent variables are used to identify key variables that significantly affect commuting times. To improve estimations for empirical results, five independent variables are applied by using standardized units—per $km^2$, per person, and percentages, which are clearly mentioned descriptions in Table 5.

First, the businesses variable is defined by the number of companies that are registered as companies and small businesses in each district office. This research hypothesizes that increasing the number of businesses will be associated with shorter commuting times. To support the hypothesis, this research assumed that a higher number of businesses have higher potential opportunities to access workplaces because of clustered employment centers. From the assumption, people tend to have shorter commuting times if they live closer to workplaces. Second, the low education variable includes the proportion of lower educated people per total population in each district. Lower educated people are defined as persons who only have a high school diploma or did not complete a high school education. This research hypothesizes that people with lower education levels tend to have longer commuting times. To support the hypothesis, this research assumed that people with lower educational levels are linked to low income status so that they have difficulty maintaining locational balances in jobs and housing. Property values seem to increase closer to the CBD so that longer commuting times lead to locational mismatches between employment centers and residential locations (Ma & Banister, 2006). For lower educated people, housing locations mainly reflect longer commuting times. Third, the public transit stations variable is defined by the number of public transit stations—bus stations and subway stations—per $km^2$ in each district. This research hypothesizes that the number of transit stations will be associated with shorter commuting times. To support the hypothesis, a higher availability of public transit stations corresponds to shorter commuting times, which can be verified by the positive effect of the reformation of public transit policies. The density is defined as the number of people per $km^2$ in the 25 districts. The last variable is car ownership which is determined by the number of private vehicle registrations per person in each district. It is hypothesized that a higher number of private vehicle registrations will be related with longer commuting times. To support the hypothesis, the research assumed that higher car ownership can cause traffic congestion closer to the CBD resulting in longer commuting times.

The condition of the independent variables is based on previous research and the characteristics of the urban spatial structure in Seoul. The results are presented in Table 6 and Table 7. In addition, analysis results are discussed in the next section.

**Table 5**
Variable Descriptions.

| Variables | Labels | Descriptions |
|---|---|---|
| Dependent variable | Average commuting times* | To calculate average commuting times from origin to destination |
| Independent variables | Business density** | Number of businesses per $km^2$ in each district |
| | Proportion of low education population*** | Proportion of lower educated people per number of total population in each district (number of people with only a high school diploma and those who did not complete a high school education) |
| | Public transit stations** | Number of public transit stations (bus and subway stations) per $km^2$ in each district |
| | Population density** | Number of people per $km^2$ in each district |
| | Car ownership**** | Number of private vehicle registrations per number of total population in each district |

N=25 districts (Gu) in Seoul; * Unit = minutes; ** Unit = per $km^2$; *** Unit = %; **** Unit = per person

# 4. RESULTS

This research supports the idea of spatial disparity of jobs and housing in commuting times. In Fig. 2, a conceptual model is conceived based on previous studies the characteristics of the urban spatial structure in Seoul. It is used to explain the relationships between commuting times and socioeconomic variables. This study hypothesizes that the number of public transit stations, density, and businesses will be associated with shorter commuting times. In contrast these variables, people with low education levels and people who own cars are expected to have longer commuting times.

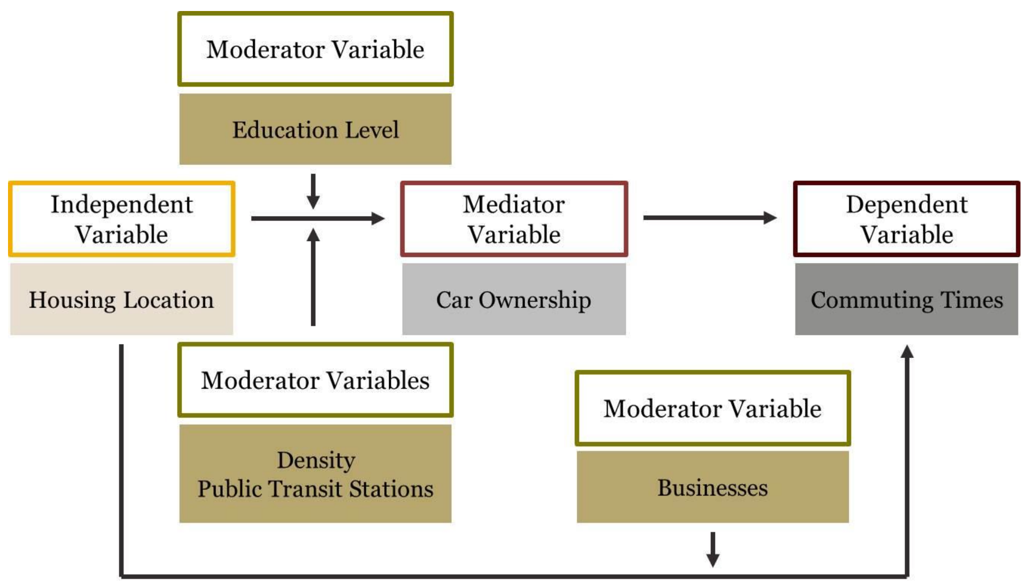



**Fig. 2.** A Conceptual Model of the Research.

Table 6 contains the frequency distribution of dependent and independent variables. Among the 25 districts, commuting time is on average 26 minutes. The highest average commuting time between origin and destination is about 36 minutes in the Dobong district and lowest average commuting time is about 17 minutes in the Seocho district. The largest proportion of lower educated population, 42.77 percent, appears in the Jungnang district and seemed to have longer average commuting times of about 29 minutes. In contrast, the district with the smallest proportion of lower educated population, 15.04 percent, in the Seocho district had relatively shorter commuting times, 17 minutes. The number of public transit stations per $km^2$ ranged from about 10 stations which is the minimum availability of transit stations per $km^2$ in the Gwanak district to about 27 stations which is the largest availability of transit stations per $km^2$ in the Dongdaemun district. Among the 25 districts, density on average is approximately 18,404 people per $km^2$. The highest population density in Seoul is the Yangcheon district, which has about 29,036 people per $km^2$ and the lowest population density is in the Jongro district with about 7,502 people per $km^2$. The results found that the Seocho district has the shortest average commuting time among the 25 districts due to a higher availability of the public transit stations, the small proportion of lower educated population, and the low population density.

For the multiple regressions, five independent variables are included in the analysis. Table 7 reports the results of the regression models for all variables. These major factors—proportion of lower educated population and the number of public transit

**Table 6**

Summary Statistics of All Variables in the 25 Districts in Seoul.

| Variables | Labels | Districts | Mean | SD | Min | Max |
|---|---|---|---|---|---|---|
| Dependent variable | Average commuting times* | 25 | 25.64796 | 4.951203 | 16.97128 | 35.94308 |
| Independent variables | Business density** | 25 | 1,389.094 | 996.3436 | 690.86 | 5,814.66 |
| | Proportion of low education population*** | 25 | 31.934 | 6.463817 | 15.04 | 42.77 |
| | Public transit stations** | 25 | 16.3512 | 4.463032 | 10.3 | 27.11 |
| | Population density** | 25 | 18,403.97 | 5,094.908 | 7,501.547 | 29,035.8 |
| | Car ownership**** | 25 | .2832 | .0582895 | .21 | .42 |

* Unit = minutes; ** Unit = per $km^2$; *** Unit = %; **** Unit = per person

**Table7**
Multiple Regression Results of Average Commuting Times in the 25 Districts in Seoul.

| Variables | Model with average commuting times | |
|---|---|---|
| | OLS Coefficient | OLS SE |
| Business density | -.0016698 | .0010885 |
| Proportion of low education population | .6629854** | .2071348 |
| Public transit stations | -.4029256** | .205221 |
| Population density | .0003112 | .0002069 |
| Car ownership | 41.29967 | 29.62766 |

*Note*. OLS = Ordinary Least Squares. The symbols *, **, and *** represent statistical significance at *$p<0.10$, **$p<0.05$, and ***$p<0.001$, respectively.

stations—have a statistically significant association with average commuting times according to the small p-values at the .05 level.

Among the five variables, the proportion of lower educated population is the most significant and positively associated with commuting times, as shown by the results of the multiple regression ($p=.005$). The results from the multiple regression models show that lower education levels contribute to longer commuting times. Furthermore, it can be implied that lower education levels lead to a low income status and these will be correlated with each other, which will cause longer commuting times. The number of public transit stations in a district is negatively associated with commuting times ($p<.05$). That is, higher availability of public transit stations corresponds to shorter commuting times, which led to the reformation of public transit policies.

This research assumed that commuting times are influenced by the number of businesses, density, and car ownership. However, these three variables have no impact on commuting times according to the multiple regression results. The influence of these variables is not noticeable in the results. Many studies found that commuting time is negatively associated with car ownership and density (Van Acker & Witlox, 2011). However, the results indicate that the number of private vehicle registrations is not significantly associated with commuting times in Seoul ($p=.179$).

This research also tested the correlations among variables. In Table 8, the results from the correlation of variables show strengthened relationships between two variables. Among the six variables, average commuting times and the proportion of lower educated population showed a moderately high correlation as well as a positive relationship. The results found that a lower educated population tends to have longer commuting times, which results are consistent with the multiple regression results. The correlations between the number of public transit stations and average commuting times, car ownership and average commuting times, and car ownership and proportion of lower educated population have negative relationships. In particular, the correlation for car ownership and average commuting times showed a moderately high relationship. The result suggests that having a car is associated with shorter commuting times. The number of businesses is negatively related with average commuting times or has a weak correlation. Finally, it can be concluded with the OLS regression and correlations of variables that the number of businesses does not influence either long or short commuting times.

**Table 8**
Correlations among Variables.

| | Average commuting times | Business density | Proportion of low education population | Public transit stations | Population density | Car ownership |
|---|---|---|---|---|---|---|
| Average commuting times | 1.0000 | | | | | |
| Business density | -0.2207 | 1.0000 | | | | |
| Proportion of low education population | 0.5963 | 0.0938 | 1.0000 | | | |
| Public transit stations | -0.3055 | 0.4318 | 0.0308 | 1.0000 | | |
| Population density | 0.2785 | 0.0077 | 0.3525 | 0.2219 | 1.0000 | |
| Car ownership | -0.5004 | 0.3878 | -0.6980 | 0.2161 | -0.5423 | 1.0000 |

# 5. DISCUSSION

This research was conducted to examine the relationships between commuting times and socioeconomic variables, which are based on previous studies of the characteristics of the urban spatial structure in Seoul. For empirical analysis, the research employed stratified sampling to produce more accurate estimations based on a proportional allocation of the total observations to different strata. The multiple regressions analyzed the associations between commuting times and five socioeconomic and built environment variables among the 25 districts in Seoul. This study has hypothesized that the number of public transit stations, population density, and the number of businesses will be associated with shorter commuting times. In contrast the other two variables, people with low educational levels and car ownership are expected to have longer commuting times.

The findings of the study have produced commuting patterns which focused on associations between average commuting times and key variables during morning commute periods. The average commuting time is clearly shown by the jobs-housing imbalances in Seoul based on the five independent variables: the number of businesses, proportion of lower educated population, the number of public transit stations, population density, and car ownership.

Among the significant variables, first, it is expected that people with lower levels of education tend to have longer commuting times and apparently have difficulty with access to jobs. The results from the multiple regressions analysis show that the number of people with a low education level is the most significant and positively associated with commuting times (p=.005). From the correlation results, average commuting times and the proportion of lower educated population showed a moderately high correlation as well as a positive relationship. The results confirmed that a lower educated population tends to have longer commuting times and the correlation result agrees with the multiple regression results.

To support the idea that lower levels of education contribute to longer commuting times, this research assumed that lower education levels were linked to people's economic conditions as well as occupational status, which plays an important role in determining the length of commuting patterns (Sang et al., 2011). As mentioned earlier, urban economic theory supports the observation that low income commuters and women are associated with longer commutes because of the high cost of living near employment centers. Also, Zolnik (2010) determined that the income level of commuters relies heavily on time costs according to urban economic theory. It implies that low education levels lead to a low income status which will cause longer commuting times.

Based on the empirical results and previous studies, this research found that long commuting times imply jobs-housing imbalances, which cause a tradeoff between property values and longer commuting patterns when choosing residential locations (Giuliano & Small, 1993; Ma & Banister, 2006). To be specific, housing prices are highly correlated with commuting times because sub-employment centers have grown rapidly and are still located in Seoul. Property values seem to increase closer to the CBD so that longer commuting times lead to locational mismatches between employment centers and residential locations (Ma & Banister, 2006). To support this idea, Fig. 3 presents the number of businesses per $km^2$ in the 25 districts in Seoul and Fig. 4

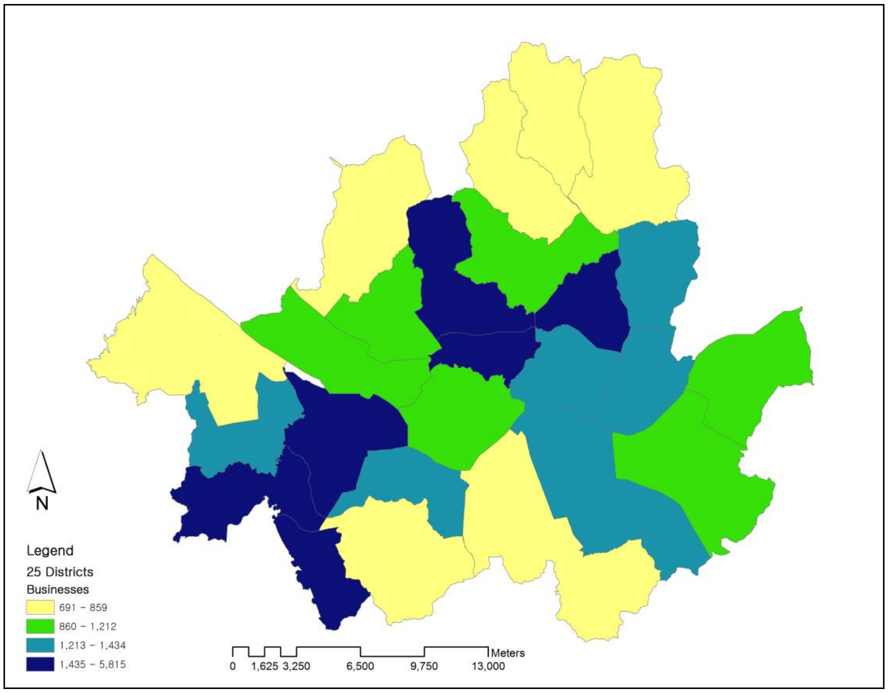



**Fig. 3.** The Number of Businesses per $km^2$ in the 25 Districts.

shows proportion of lower educated population in the 25 districts in Seoul. To compare these distributions in the 25 districts, districts with lower education levels do not quite correspond to the employment centers among the 25 districts in Seoul. The result indicates that people with lower educational levels have difficulty maintaining locational balances in jobs and housing. As a result, spatial imbalances arise in that workers who live near their workplaces find it beyond their ability to pay housing costs so that housing costs mainly reflect commuting patterns (Giuliano & Small, 1993). This implies that accessibility is a determining factor in maintaining balance between jobs and housing (Ma & Banister, 2006; Zhao et al., 2009). Accessibility impacts how residential and employment locations are chosen and how individual commuting patterns are decided.

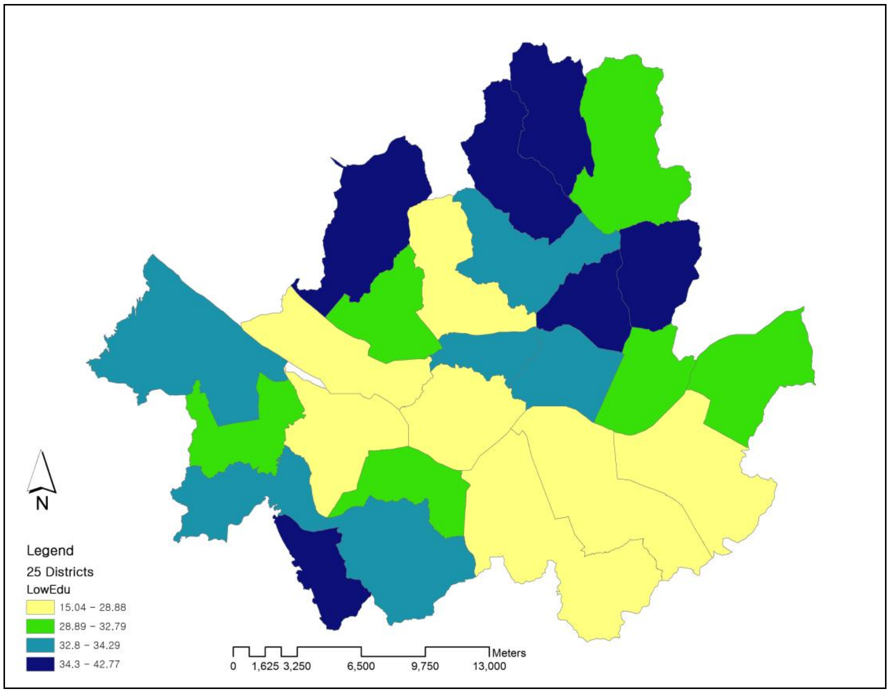



**Fig. 4.** Population Proportion of Lower Education Levels in the 25 Districts.

Second, this research found that a higher availability of public transit stations in the 25 districts tends to result in shorter commuting times. It can be implied that the reformation of public transit policies mitigates the inconvenience in using the public transportation system and minimizes traffic congestion during the peak commuting periods. The results from the multiple regressions analysis showed that the number of public transit stations is significant and negatively associated with commuting times ($p<.05$). Also, the correlation for these variables confirmed that the number of public transit stations and average commuting times showed a moderately high relationship as well as were negatively correlated with each other. From these results, it can be verified that a higher availability of public transit stations corresponds to shorter commuting times, which reinforces the positive effect of the reformation of public transit policies.

According to the correlation results, one of the interesting findings is relationships between car ownership and two variables—average commuting times and proportion of lower educated population. In particular, the correlation for car ownership and average commuting times showed a high negative correlation. The result suggests that having a car is associated with shorter commuting times. Also, the correlation for car ownership and the proportion of low education population showed a highly negative relationship. It can be interpreted that car ownership is related to income status and lower education levels resulted in lower income status.

Previous research has found that areas of low density tend to have shorter commuting times due to changing locations and choosing diverse transit modes (Gordon et al., 1991). Population movement corresponds to job locations and employment decentralization tends to reduce commuting time and distance (Kim, 2008; Mieszkowski & Mills, 1993). On the other hand, high density resulted in long commuting times closer to the CBD because of traffic congestion (Gordon et al., 1989). High density developments contributed to extensive urban sprawl in the SMA (Kwon, 2003). Although empirical results support that Seoul is a highly dense city, it cannot be verified that population density can cause an increase or decrease in average commuting times in the 25 districts based on the multiple regression results and correlations.

# 6. CONCLUSIONS

This research aimed to examine the relationships between commuting times and imbalances in jobs and housing based on an empirical analysis of commuting times and socioeconomic variables. To analyze the relationships between commuting time and associated factors, this research applied the smart card data that integrates individual travel information in Seoul. Instead of commuting times, many previous studies focused on commuting distances at the district level. To achieve significant results, the stratified sampling technique employed to consider the different conditions among the 25 districts, refer to an individual stratum. Moreover, examining commuting times is possible due to the smart card data that recorded time factors for both origin and destination. Due to these aspects, the research was able to obtain more significant results than previous research on population movement and calculate commuting times in the 25 districts of Seoul.

The analysis results are summarized from the multiple regression model and correlations between variables. The regression analysis found that average commuting times are significantly associated with two variables: the proportion of population in lower levels of education and the number public transit stations. The number public transit stations per $km^2$ are associated with shorter commuting times. On the other hand, a higher proportion of lower educated population produces longer commuting times. According to the correlation results, car ownership has a moderately high correlation with average commuting times and the proportion of lower educated population.

However, the number of businesses, density, and car ownership were insignificant in the regression analysis and the number of businesses lacked correlations with the other variables.

The analysis suggests that commuting time is associated with socioeconomic characteristics and seems to be important for determining demographic movement as well as locational advantages in certain regions of Seoul. All the empirical results from this research suggest that land use planning and public transit policy should be integrated to reduce commuting times.

# 7. LIMITATIONS AND FUTURE RESEARCH

## 7.1 Research Limitations

Many previous studies are more focused on analyzing commuting distances instead of commuting times. The reason is that commuting distances are easy to measure by two methods: Euclidian distances and network analysis in GIS. Also, there is easy access to data for distances. Another reason is that U.S. cities generally have more sprawl and the urban structures are dependent on private vehicles instead of public transit as in Seoul. To consider urban sprawl and decentralization of workplaces in U.S. cities according to previous studies, analyzing commuting distances was a more effective way to measure the jobs-housing imbalance. However, measuring commuting distances tend to lead to under or over estimations.

As to the methodological limitations of the research design, this research found that the district level data has a coarseness which can be misleading. Accordingly, this research applied stratified sampling approach. Also, several districts have relatively small trip observations as well as key variable data compared to other districts. In particular, the car ownership variable does not follow the normal distribution and there are big differences of the number of vehicle among the 25 districts.

In addition, the lack of available housing data is limited to analyzing associations with average commuting times. Due to the data access limitation, this research hypothesized that lower educated people are linked to income status as well as impacts on housing prices, which can be an alternative variable to obtain adequate results. The problem with the data access is that the Ministry of Land, Transportation and Maritime Affairs (MLTM) only provides information on fluctuation rates of land prices in Korea instead of individual property values. As a result, this study cannot statistically examine associations between commuting times and housing values.

Based on the limited research of commuting times, a study to examine commuting times in Seoul is challenging. In particular, it is hard to interpret relationships between commuting times and socioeconomic characteristics as well as support clear explanations without relevant previous research. The reason is that Seoul has different urban spatial structures such as high population density and concentrated employment centers in the inner city unlike U.S. cities.

To overcome the limitations, this research suggests comparing different urban spatial structures of U.S. cities and Seoul by applying commuting times, the results of which can be generalized in different urban spatial structures.

### 7.2 Addressing for Future Research

First, the unit of analysis in this research is conducted at the district level. Seoul has 424 neighborhoods among the 25 districts. Therefore, changing the unit of analysis from the district to the neighborhood by standardized variables can cause more significant associations between commuting times and socioeconomic characteristics. For obtaining adequate data, collecting data and applying survey research methods should be considered a long-term process.

In addition, due to the data access limitations, especially gender, this study cannot examine relationships between commuting times and gender. If this study that adds gender as an independent variable in the multiple regression models and correlations, the results will contribute to the analysis of population movement based on gender as well as determining the impact on women commuters in urban spatial structure.

# REFERENCES

Aguiléra, A., Massot, M.-H., & Proulhac, L. (2009). Exploring the relationship between work and travel behavior on weekdays: Analysis of paris region travel survey over 20 years. *Journal of the Transportation Research Board, 2135*, 69-77.

Alexander, B., Dijst, M., & Ettema, D. (2010). Working from 9 to 6? An analysis of in-home and out-of-home working schedules. *Transportation, 37*, 505-523.

Badamdorj, C. (2004). Korean experiences on the urban functional zoning and land use management: The case of Seoul. *Mongolian Geographical Review, 4,* 1-13.

Bae, C.-H. C., Jun, M.-J., & Park, H. (2003). The impact of Seoul's subway line 5 on residential property values. *Transport Policy, 10*(2), 85-94.

Bae, Y., Yoon, M., & Kim, E. (2008). Spatial patterns of population growth and social indicators' change in Korea: An exploratory spatial data analysis. *International Journal of Urban Sciences, 12*(2), 61-72.

Bagley, N. M., & Mokhtarian, L. P. (2002). The impact of residential neighborhood type on travel behavior: A structural equations modeling approach. *The Annals of Regional Science, 36*, 279-297.

Capozza, D. R., & Helsley, R. W. (1989). The foundamentals of land prices and urban growth. *Journal of Urban Economics*, *26*, 295-306.

Cervero, R., & Kang, C. D. (2009). Bus rapid transit impacts on land uses and land values in Seoul, Korea. *UC Berkeley Center for Future Urban Transport: A Volvo Center of Excellence, Institute of Transportation Studies, UC Berkeley*, 1-38.

Cervero, R., & Kang, C. D. (2011). Bus rapid transit impacts on land uses and land values in Seoul, Korea. *Transport Policy, 18*(1), 102-116.

Cervero, R., & Wu, K.-L. (1998). Sub-centring and commuting: Evidence from the San Francisco Bay Area, 1980-90. *Urban Studies, 35*(7), 1059-1076.

Cho, C.-J. (2002). The Korean growth-management programs: Issues, problems and possible reforms. *Land Use Policy, 19*, 13-27.

Cho, J. (2005). Urban planning and urban sprawl in Korea. *Urban Policy and Research, 23*(2), 203-218.

Dubin, R. (1991). Commuting patterns and firm decentralization. *Land Economics, 67*(1), 15-29.

Giuliano, G. (1998). Information technology, work patterns and intra-metropolitan location: A case study. *Urban Studies, 35*(7), 1077-1095.

Giuliano, G., Moore II, J. E., & Golob, J. (2000). Integrated smart-card fare system: Results from field operational test. *Journal of the Transportation Research Board*, *1735*, 138-146.

Giuliano, G., & Small, K. A. (1993). Is the journey to work explained by urban structure? *Urban Studies, 30*(9), 1485-1500.

Gordon, P., Kumar, A., & Richardson, H. W. (1989). The influence of metropolitan spatial structure on commuting time. *Journal of Urban Economics*, *26*, 138-151.

Gordon, P., Richardson, H. W., & Jun, M.-J. (1991). The commuting paradox: Evidence from the top twenty. *Journal of the American Planning Association, 57*(4), 416-420.

Ha, S.-K. (2010). Housing, social capital, and community development in Seoul. *Cities, 27*, 35-42.

Henderson, D. A. (1997). *Urbanization of Rural America*. New York: Nova Science Publishers, Inc.

Henderson, V. (2002). Urbanization in developing countries. *The World Bank Research Observer, 17*(1), 89-112.

Jang, W. (2010). Travel time and transfer analysis using transit smart card data. *Journal of the Transportation Research Board*, *2144*, 142-149.

Joh, C.-h. (2009). Daily travel pattern using public transport mode in Seoul: An analysis of a multi-dimensional motif search. *Journal of the Korean Geographical Society*, *44*(2), 176-186.

Johnston-Anumonwo, I. (1992). The influence of household type on gender differences in work trip distance. *The professional Geographer, 44*(2), 161-169.

Jun, M.-J., & Bae, C.-H. C. (2000). Estimating the commuting costs of Seoul's greenbelt. *International Journal of Urban Sciences Review, 23*, 300-315.

Jun, M.-J., & Ha, S.-K. (2002). Evolution of empolyment centers in Seoul. *Review of Urban & Regional Development Studies*, *14*(2), 117-132.

Jun, M.-J., & Hur, J.-W. (2001). Commuting costs of "leap-frog" newtown development in Seoul. *Cities, 18*(3), 151-158.

Kim, C. (2008). Commuting time stability: A test of a co-location hypothesis. *Transportation Research A, 42*, 524-544.

Kim, C., Sang, S., Chun, Y., & Lee, W. (2012). Exploring urban commuting imbalance by jobs and gender. *Applied Geography, 32*, 532-545.

Kim, H. M., & Han, S. S. (2012). Seoul. *Cities, 29*, 142-154.

Kim, J., & Kang, S. (2005). Development of integrated transit-fare card system in the Seoul Metropolitan Area. *Springer, 3683*, 95-100.

Kim, K.-H., & Mills, E. S. (1988). Korean development and urbanization: Prospects and problems. *World Development*, *16*(1), 157-167.

Kim, K. S., Cheon, S.-h., & Lim, S.-j. (2011). Performance assessment of bus transport reform in Seoul. *Transportation*, *38*(5), 719-735.

Kwon, T.-H. (2003). Demographic trends and their social implications. *Social Indicators Research 62*(1), 19-38.

Larson, J. (1993). Density is density. *American Demographics, 15*(2), 38-43.

Layman, C. C., & Horner, M. W. (2010). Comparing methods for measuring excess commuting and jobs-housing balance. *Journal of the Transportation Research Board*, *2174*, 100-117.

Lee, B. S., & McDonald, J. F. (2003). Determinants of commuting time and distance for Seoul residents: The impact of family status on the commuting of women. *Urban Studies*, *40*(7), 1283-1302.

Lee, K., Jung, W.-S., Park, J. S., & Choi, M. Y. (2008). Statistical analysis of the metropolitan Seoul subway system: Network structure and passenger flows. *Physica A: Statistical Mechanics and its Applications, 387*(24), 6231-6234.

Lee, S., & Lee, S. (2005). Transport policy directions based on travel pattern analysis in the Seoul Metropolitan Area. *International Journal of Urban Sciences, 9*(1), 40-48.

Lee, S., Lee, S., & Lee, Y.-I. (2006). Innovation public transportation oriented policies in Seoul. *Transportation, 33*, 189-204.

Lee, Y. J., & Zang, H. (1998). Urbanisation and regional productivity in Korea manufacturing. *Urban Studies, 35*(11), 2085-2099.

Levinson, D. M. (1997). Job and housing tenure and the journey to work. *The Annals of Regional Science, 31*, 451-471.

Levy, J. (2009). *Contemporary Urban Planning*. New Jersey: Pearson Prentice Hall.

Ma, K.-R., & Banister, D. (2006). Extended excess commuting: A measure of the jobs-housing imbalance in Seoul. *Urban Studies, 43*(11), 2099–2113.

Madden, J. (1981). Why women work closer to home. *Urban Studies, 18*(2), 181-194.

Matsuo, M. (2011). US metropolitan spatial structure and labour accessibility. *Urban Studies, 48*(11), 2283-2302.

Mieszkowski, P., & Mills, E. S. (1993). The causes of metropolitan suburbanization. *Journal of Economic Perspectives, 7*(3), 135-147.

Murphy, E. (2009). Excess commuting and modal choice. *Transportation Research Part A, 43*, 735-743.

Pucher, J., Park, H., & Kim, M. H. (2005). Public transportation reforms in Seoul: Innovations motivated by funding crisis. *Journal of Public Transportation, 8*(5), 41-62.

Rii, H. U., & Ahn, J.-S. (2001). Urbanization and its impact on Seoul, Korea. In *2001 Forum on Urbanizing World and UN Human Habitat II*, New York.

Rosenbloom, S. (2006). Understanding women' and men's travel patterns: The research challenge. In *2005 Transportation Research Board Conference*, Washington.

Sang, S., O'Kelly, M., & Kwan, M.-P. (2011). Examining commuting patterns: Results from a journey-to-work model disaggregated by gender and occupation. *Urban Studies, 48*(5), 891-909.

Silva, J. d. A. e., & Goulias, K. G. (2009). Structural equations model of land use patterns, location choice, and travel behavior: Seattle, Washington, compared with Lisbon, Portugal. *Journal of the Transportation Research Board, 2135*, 106-113.

Sohn, J. (2002). *Spatial econometric modeling of urban spatial sturcture of Chicago and Seoul in the 1990s: Agglomeration economies, information technology and commuting.* PhD. University of Illinois at Urbana-Champaign.

Sohn, J. (2005). Are commuting patterns a good indicator of urban spatial structure? *Journal of Transport Geography, 13(4)*, 306-317.

Suzuki, T., & Lee, S. (2012). Jobs-housing imbalance, spatial correlation, and excess commuting. *Transportation Research A, 46*, 322-336.

Turner, T., & Niemeier, D. (1977). Travel to work and household responsibility: New evidence. *Transportation, 24*, 397-419.

Van Acker, V., & Witlox, F. (2011). Commuting trips within tours: How is commuting related to land use? *Transportation, 38*, 465-486.

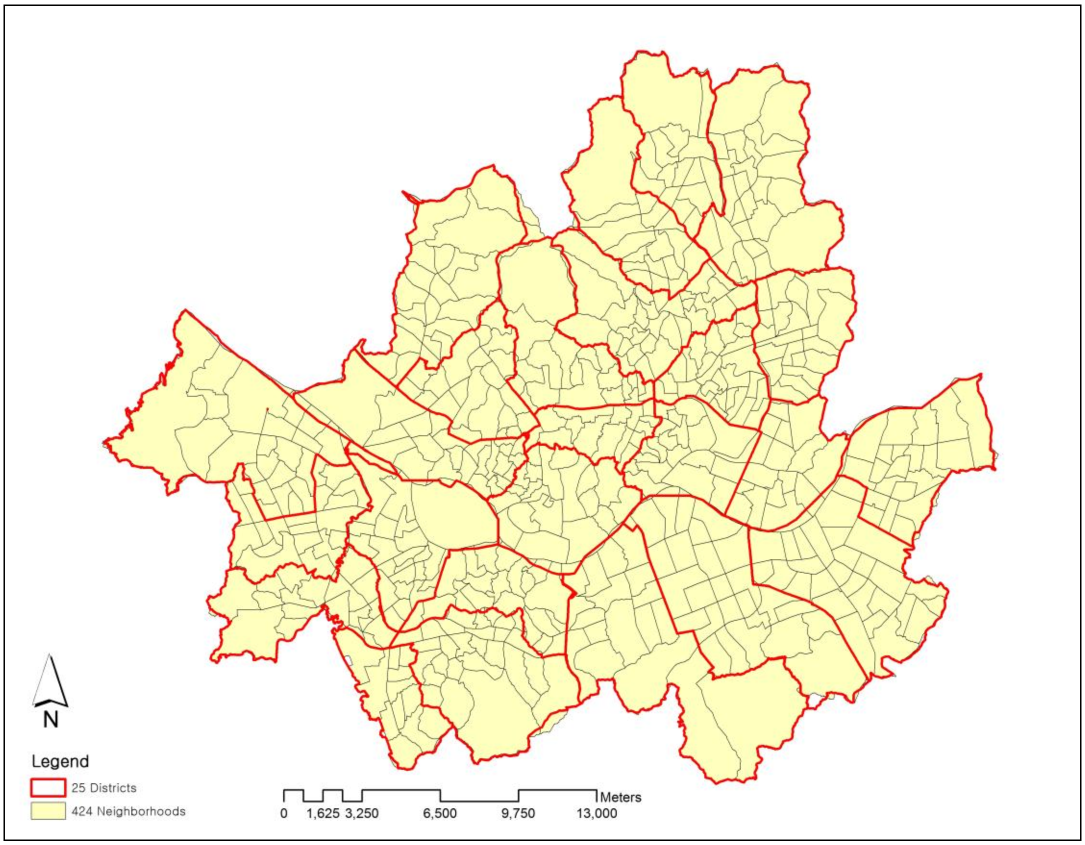
Weinberger, R. (2007). Men, women, job sprawl, and journey to work in the Philadelphia region. *Public Works Management Policy, 11*, 177-193.

Zhao, P., Lu, B., & Linden, G. J. J. (2009). The effects of transport accessibility and jobs–housing balance on commuting time: Evidence from Beijing. *International Planning Studies, 14*(1), 65-83.

Zolnik, E. J. (2010). Multilevel models of commute times for men and women. *Advances in Spatial Science,* Part 2, 195-215.

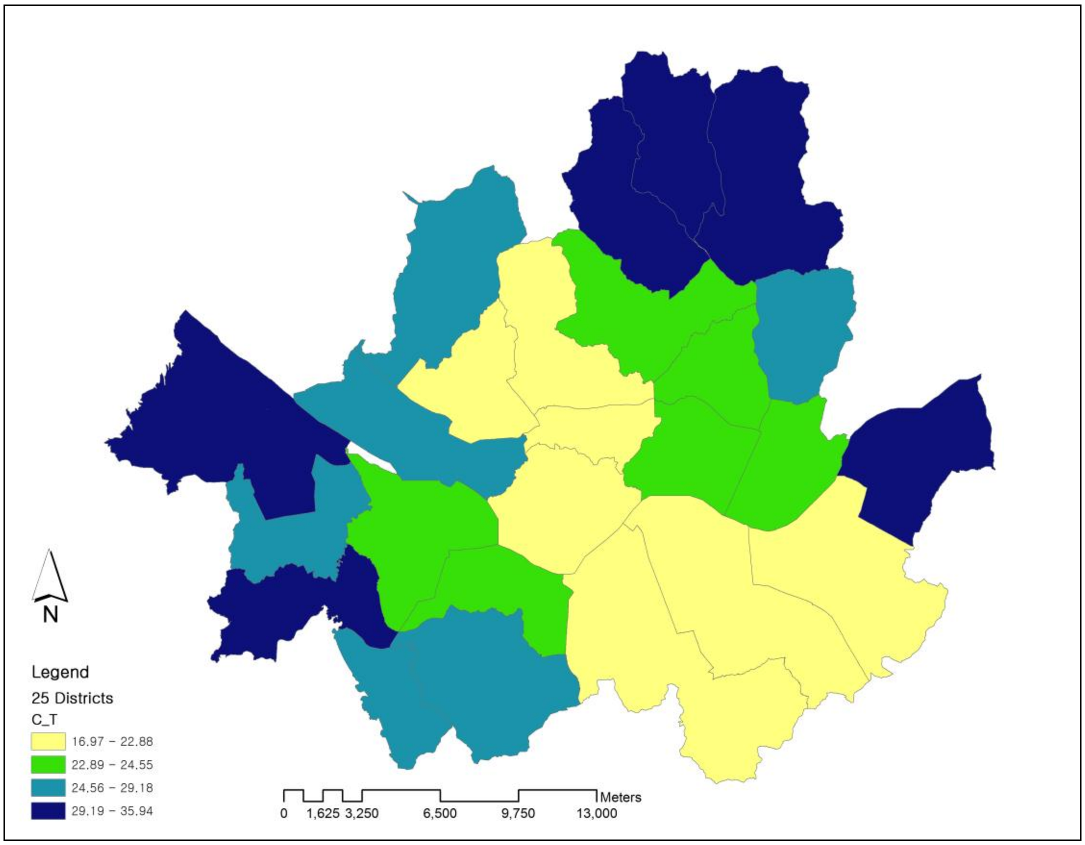
# APPENDIX A

A Map of Seoul.

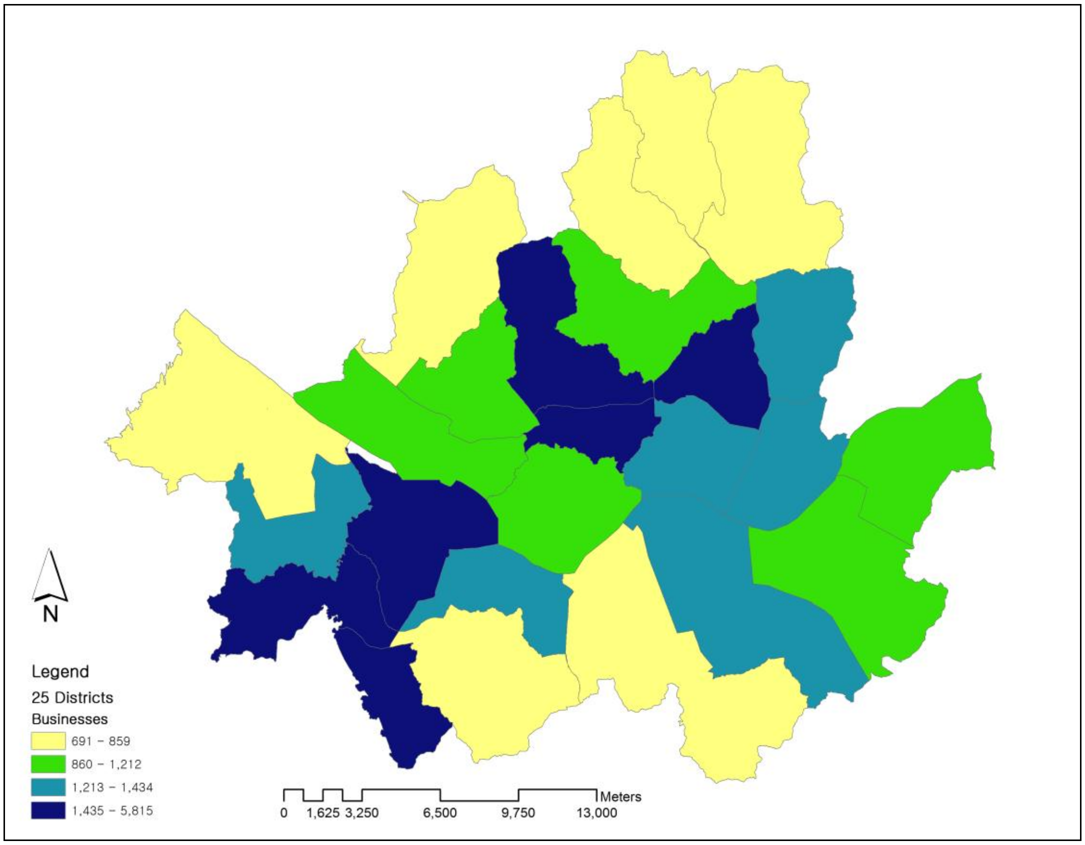


# APPENDIX B

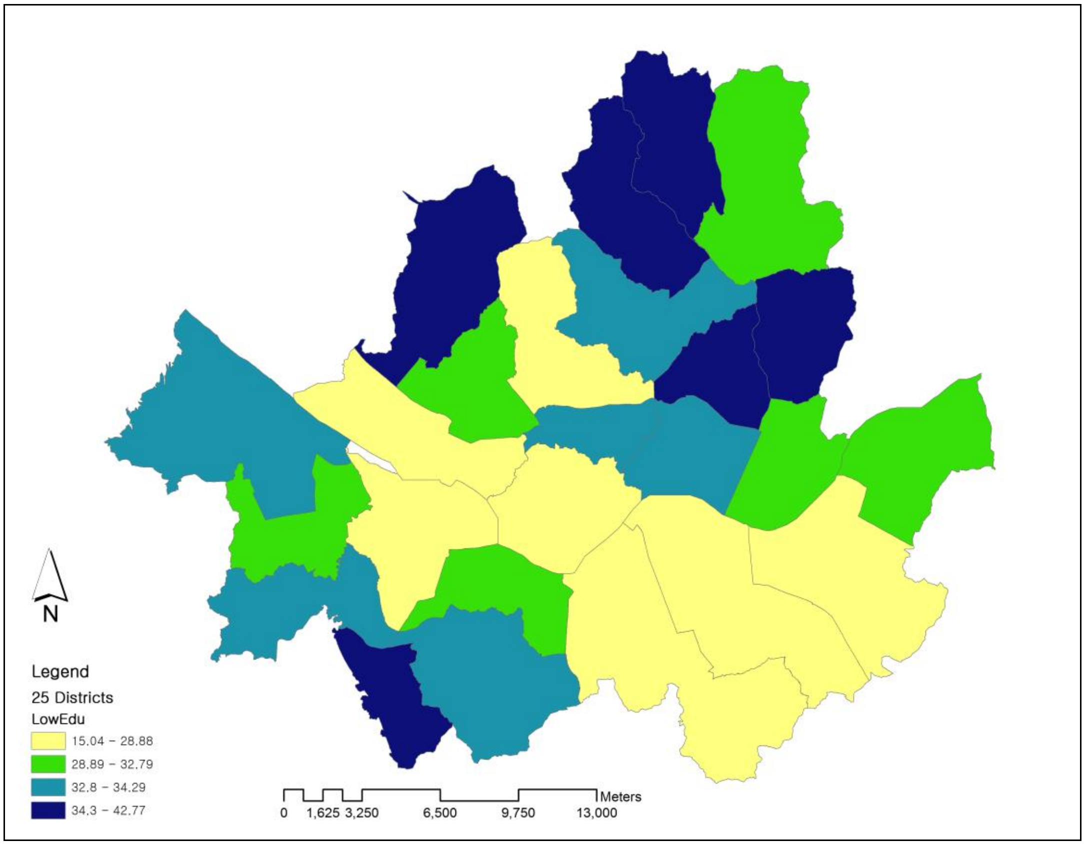
Average Commuting Times in the 25 Districts of Seoul.



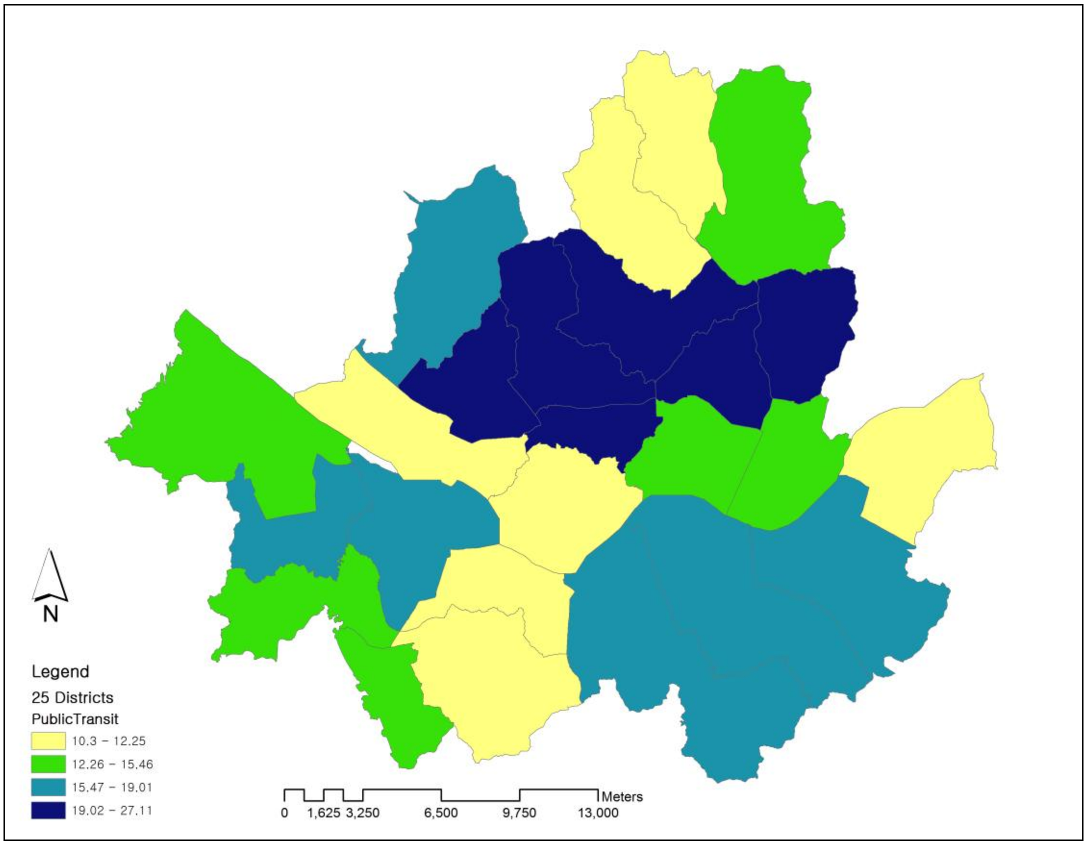
The Number of Businesses per $km^2$ in the 25 Districts of Seoul.



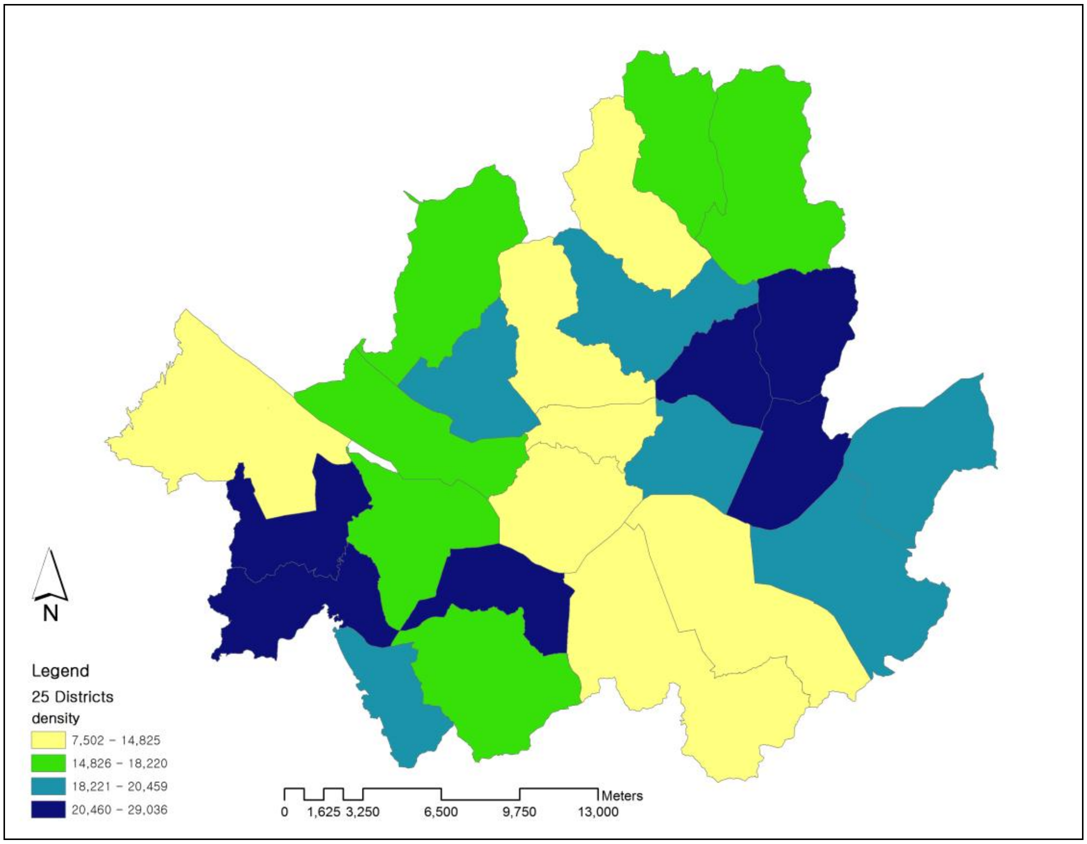
Population Proportion of Lower Education Levels in the 25 Districts of Seoul.



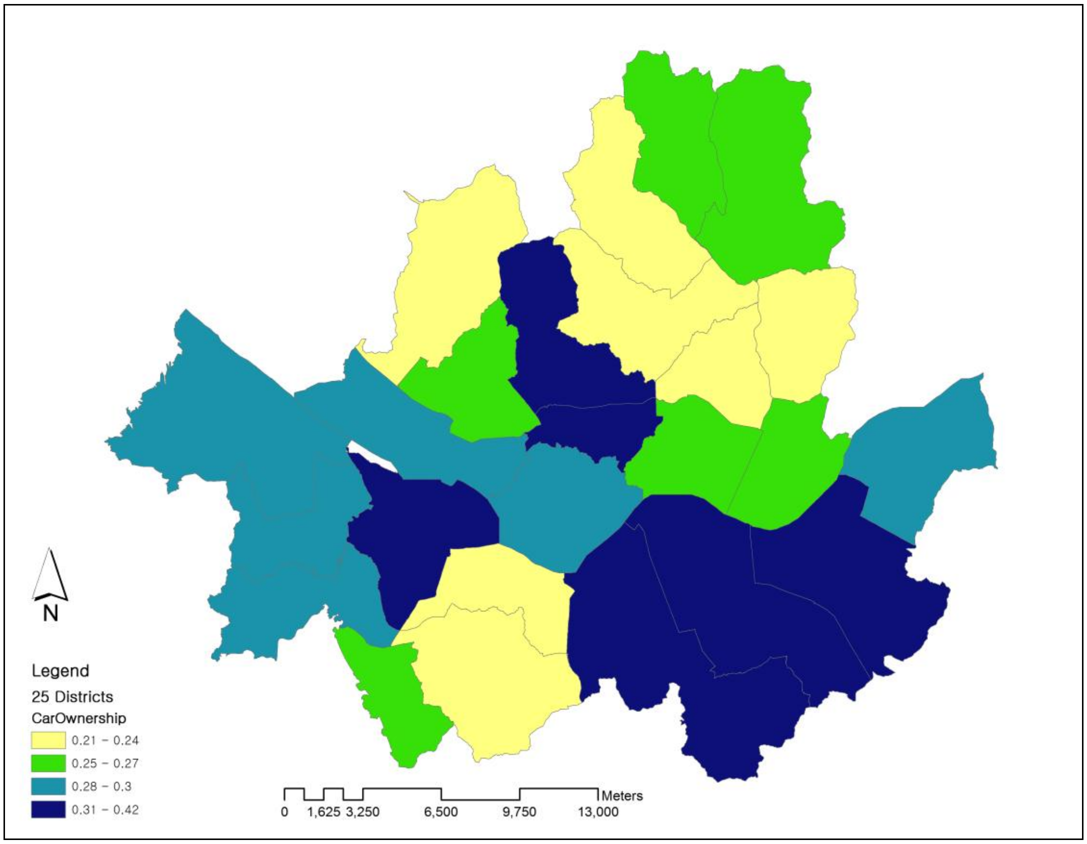
The Number of Public Transit Stations per km$^2$ in the 25 Districts of Seoul.



Population Density in the 25 Districts of Seoul.



Vehicle Ownership per Person in the 25 Districts of Seoul.



# APPENDIX C

Observations for All Independent Variables in the 25 Districts of Seoul.

| Districts | Businesses | Low education population | Public transit stations | Population density | Car ownership |
|---|---|---|---|---|---|
| Gangnam-gu | 53,494 | 97,715 | 746 | 14,605.67 | 242,411 |
| Kangdong-gu | 28,124 | 162,935 | 272 | 20,217.21 | 137,821 |
| Gangbuk-gu | 19,256 | 148,843 | 267 | 14,824.52 | 72,011 |
| Gangseo-gu | 30,724 | 199,039 | 588 | 14,011.73 | 176,295 |
| Gwanak-gu | 24,922 | 178,521 | 299 | 18,220.47 | 119,436 |
| Gwangjin-gu | 23,791 | 125,409 | 245 | 22,802.05 | 93,620 |
| Guro-gu | 32,381 | 152,558 | 298 | 22,509.55 | 136,886 |
| Geumcheon-gu | 24,520 | 105,052 | 201 | 20,349.54 | 71,846 |
| Nowon-gu | 24,491 | 198,274 | 534 | 17,360.37 | 155,356 |
| Dobong-gu | 17,498 | 137,810 | 247 | 17,909.86 | 94,054 |
| Dongdaemun-gu | 29,671 | 138,999 | 385 | 26,714.3 | 89,380 |
| Dongjak-gu | 19,836 | 122,921 | 200 | 25,356.25 | 95,696 |
| Mapo-gu | 28,930 | 115,665 | 291 | 16,776.87 | 108,829 |
| Seodaemum-gu | 17,887 | 108,301 | 344 | 18,969.94 | 80,349 |
| Seocho-gu | 36,302 | 66,171 | 776 | 9,362.149 | 168,493 |
| Seongdong-gu | 23,148 | 108,008 | 247 | 18,806.65 | 85,945 |
| Seongbuk-gu | 23,593 | 168,902 | 549 | 20,256.08 | 112,481 |
| Songpa-gu | 40,931 | 174,161 | 595 | 20,458.8 | 212,554 |
| Yangcheon-gu | 24,562 | 147,249 | 317 | 29,035.8 | 146,662 |
| Yeongdeunpo-gu | 41,084 | 128,535 | 467 | 18,145.28 | 145,699 |
| Yongsan-gu | 18,966 | 71,734 | 231 | 11,757.8 | 75,184 |
| Eunpyeong-gu | 22,666 | 179,141 | 472 | 16,602.39 | 111,402 |
| Jongro-gu | 37,636 | 50,728 | 458 | 7,501.547 | 72,631 |
| Jung-gu | 57,914 | 47,804 | 219 | 14,176.71 | 53,299 |
| Jungnang-gu | 26,526 | 184,892 | 451 | 23,367.68 | 103,153 |

Observations for All Standardized Independent Variables in the 25 Districts of Seoul.

| Districts | Business density* | Low** education population | Public transit stations* | Population density* | Car*** ownership |
|---|---|---|---|---|---|
| Gangnam-gu | 1,353.94 | 16.93 | 18.88 | 14,605.67 | 0.42 |
| Kangdong-gu | 1,144.18 | 32.79 | 11.07 | 20,217.21 | 0.28 |
| Gangbuk-gu | 815.59 | 42.53 | 11.31 | 14,824.52 | 0.21 |
| Gangseo-gu | 741.59 | 34.29 | 14.19 | 14,011.73 | 0.30 |
| Gwanak-gu | 858.79 | 33.76 | 10.30 | 18,220.47 | 0.23 |
| Gwangjin-gu | 1,395.37 | 32.26 | 14.37 | 22,802.05 | 0.24 |
| Guro-gu | 1,610.19 | 33.70 | 14.82 | 22,509.55 | 0.30 |
| Geumcheon-gu | 1,886.15 | 39.71 | 15.46 | 20,349.54 | 0.27 |
| Nowon-gu | 690.86 | 32.22 | 15.06 | 17,360.37 | 0.25 |
| Dobong-gu | 845.31 | 37.17 | 11.93 | 17,909.86 | 0.25 |
| Dongdaemun-gu | 2,089.51 | 36.64 | 27.11 | 26,714.3 | 0.24 |
| Dongjak-gu | 1,215.44 | 29.70 | 12.25 | 25,356.25 | 0.23 |
| Mapo-gu | 1,211.98 | 28.88 | 12.19 | 16,776.87 | 0.27 |
| Seodaemum-gu | 1,016.31 | 32.44 | 19.55 | 18,969.94 | 0.24 |
| Seocho-gu | 772.38 | 15.04 | 16.51 | 9,362.149 | 0.38 |
| Seongdong-gu | 1,373.77 | 34.08 | 14.66 | 18,806.65 | 0.27 |
| Seongbuk-gu | 960.24 | 33.94 | 22.34 | 20,256.08 | 0.23 |
| Songpa-gu | 1,208.12 | 25.13 | 17.56 | 20,458.8 | 0.31 |
| Yangcheon-gu | 1,411.61 | 29.15 | 18.22 | 29,035.8 | 0.29 |
| Yeongdeunpo-gu | 1,672.80 | 28.84 | 19.01 | 18,145.28 | 0.33 |
| Yongsan-gu | 867.22 | 27.90 | 10.56 | 11,757.8 | 0.29 |
| Eunpyeong-gu | 763.42 | 36.34 | 15.90 | 16,602.39 | 0.23 |
| Jongro-gu | 1,574.07 | 28.28 | 19.16 | 7,501.547 | 0.40 |
| Jung-gu | 5,814.66 | 33.86 | 21.99 | 14,176.71 | 0.38 |
| Jungnang-gu | 1,433.84 | 42.77 | 24.38 | 23,367.68 | 0.24 |

* Unit = per km$^2$; ** Unit = %; *** Unit = per person

# VITA


| | |
|---|---|
| Name: | Sun Mi Jin |
| Address: | 3137 TAMU, College Station, TX 77843-3137 |
| Email Address: | kafa0455@neo.tamu.edu |
| Education: | B.E., Urban Planning and Engineering, Kangnam University, 2007<br>B.S., Real Estate Science, Kangnam University, 2007<br>M.S., Urban Planning, Texas A&M University, 2012 |