

How urban form does affect gas emission in Asian cities?

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ABSTRACT: The goal of this study is to find the relationship between the urban form and air pollution. We use the level of air pollution in Tokyo, Seoul, and Beijing, and examine the changes of urban form in the past 10 years (1997-2006) of these three cities through the Gini and Moran coefficient, which are gained from the utilization of the population and employment indexes. We inquire on the correlation among the CO, CO₂, and urban form indexes, the Gini and Moran coefficient. The results of this paper show that the emission of CO and CO₂ shares negative correlation with them Moran's I of population, and positive correlation with them Moran's I of employment. Also, they do positive correlation with a Gini coefficient of population and employment. That is, the urban form with less emission of CO and CO₂ is a metropolitan that has a polycentric urban structure that is spatially fairly clustered concerning population, and does a monocentric or polycentric urban structure that is compact distributed concerning employment.

Keywords: Urban Form, Polycentric, Moran coefficient, Gas emission, Asian cities

1. INTRODUCTION

Global efforts to reduce air pollution and greenhouse effect for the sustainable urban development are being conducted with increasing interests. Asian countries that achieved rapid economical development recently cannot be exemptions, and such ameliorative efforts are being continued in major economical cities such as Beijing, Seoul and Tokyo. However, the recent tendency appears that the degree of reduction in air pollution and greenhouse gas emission has slowed or even increased. A conjecture can be made that such tendency is due to the limitation of improvement in motor vehicular usage, which acts as the primary variable of air pollution and greenhouse gas emission, while such efforts are constantly devoted in industrial field. Therefore, not only technical

part but also a new approach in a different aspect is necessary.

This article aims to draw out implications for the establishment of a ameliorative policy; as a matter of urban form, to practice sustainable development, and to grasp the linkage between the urban form and air pollution at second hand. For such objectives, the changes in urban form and the level of air pollution in Tokyo, Seoul, and Beijing; three major cities leading the growth of Asia, the region that is becoming the center of global economy as radical industrialization and urbanization is taking place, would be observed to analyze the correlation.

2. LITERATURE REVIEWS

2.1. Relationship among Urban Form, Transportation Energy Consumption and Air Pollution

The early studies presented that among urban forms, the 'concentric or compact city' that conducts centralized land use and possesses balance in utilization of private automobile and public transportation shows the highest efficiency in reduction of air pollution and in the consumption of transportation energy (Cervero, 1989; Newman and Kenworthy, 1989; Gordon and Richardson, 1997).

Brotchie (1984) hypothesized three typical set of urban form—sprawl, compact and decentralized concentration, and presented the urban structure quantitatively by the land use and average transportation distance. Through this research, he asserted that urban form of which decentralized concentration is applied could contribute to the reduction of average transportation distance.

The researches listed above mainly focus on the connection of urban form and the variation in distance of traffic and consumption of transportation energy, while the correlation between urban form and air pollution being described through indirect description about energy consumption.

Moreover, since the analysis had been performed in a single point of view, the explanation about alteration in the urban form of a particular city is likely to be limited, thus less persuasive.

2.2. Defining Urban Form

Urban form can be generally defined as the spatial pattern of human activities (Anderson et al., 1996). Therefore, researches aimed to examine the urban form are being performed through analyzing diverse indexes of human activities, and the most representative among those is the study that classified urban form according to the distribution of population and employment in different urban spatial structures.

The characteristic of an urban form associated with the distribution of population and employment can be distinguished conceptually by the degree of compactness or sprawl of the metropolitan area. Yu-Hsin Tsai (2005) classified the metropolitan form

into monocentric form, polycentric form and decentralized sprawl, by using distinguishable indexes such as Gini, Entropy, Geary, Moran, focused on the population and Employment. Through the analysis on the data of population and employment in 219 metropolitan areas in U.S.A, he insisted that by comparing the Gini and Moran coefficient, the examination of an urban form will gain persuasion.

These studies about urban form, still, are at the level of examining the immediate relationship concerning the urban form itself or the land use in the sense of urban planning. Inquiries on the ripple effect that follows the forming of a metropolitan, for instance, consumption of transportation energy or urban air pollution, are being conducted through the vague sense of relationship with the urban form, without specific examination about it.

Noticing such aspects of recent studies, in this article, detail examination upon urban form through the comparison between Gini and Moran coefficient, and time-series analysis of related indexes in the influence of the change of urban form to air pollution and greenhouse gas emissions are performed in order to provide clear relationship among these factors.

Two main methods were applied in the progress of this research.

First is the analysis for distinguishing urban form, utilizing indexes such as Gini and Moran coefficient discussed in previous studies, with the purpose to determine and comprehend whether a particular city is classified under monocentric form, polycentric form or decentralized sprawl.

Second is a method using statistical correlation—that is, a process of analyzing the relationship between urban form and air pollution through the inquiry about the connection of Moran coefficient previously calculated and the CO, CO₂—indexes of air pollution and greenhouse emission. The goal is to draw out implications for the policy of urban development and management for the establishment of sustainable urban form.

3. URBAN FORM DISTINCTION INDEXES

Gini coefficient, Theil Index, Entrophy Index, Moran and Greary Coefficient are the most representative indexes utilized for distinguishing urban form.

Among these indexes, Gini coefficient is the one applied to measure inequality of population or employment distribution by spatial units in a metropolitan area. The value of the Gini coefficient ranges from 0 to 1, and higher value, close to 1, means that uneven distribution becomes deeper and the population or employment density is extremely high. A Gini coefficient closes to zero means that population or employment is evenly distributed without unbalanced area.

The Gini coefficient can be calculated as

$$\text{Gini} = 0.5 \sum_{i=1}^N |X_i - Y_i|$$

Where, N is the number of sub-areas; X_i is the proportion of land area in sub area i ; and Y_i is the proportion of population or employment in sub-area i (Penfold, 2001).

While Gini coefficient makes it able to grasp the degree of uneven spatial distribution of factors such as population or employment in the metropolitan, it does not provide information about whether subareas are clustered or randomly distributed. For the complementary of such aspect of Gini coefficient, Moran coefficient can be applied to estimate the level of clustering of urban form. Moran's I ranges from -1 to 1, with the value close to 1 indicating that high-density sub-areas are closely clustered, and the value close to -1 meaning scattered distribution, spatially.

The Moran's I can be calculated as

$$\text{Moran} = \frac{N \sum_{i=1}^N \sum_{j=1}^N W_{ij} (X_i - X)(X_j - X)}{\left(\sum_{i=1}^N \sum_{j=1}^N W_{ij} \right) (X_i - X)^2}$$

Where, N is the number of sub-areas; X_i is population or employment in sub-area i ; X_j is the mean of population or employment in

sub-area j ; X is the mean of population or employment; and W_{ij} denotes the weighting between sub-areas i and j (Yu-Hsin Tasi, 2005).

The pair comparison of Gini coefficient and Moran's I can be effective in distinguishing among monocentric, polycentric and sprawling forms of a metropolitan. First of all, in the analysis of uneven distribution in urban form, i.e. the sprawling level, even in the condition of same Moran coefficient, the gap between concentrated area and dispersed area becomes wider when the value of Gini coefficient is higher.

Also, in the judgement of monocentric and polycentric, even when the value of Gini coefficient is same, higher Moran's I indicates closer characteristic to the monocentric urban form, and it is possible to distinguish polycentric from decentralized sprawling form with the boundary of zero.

In conclusion, when applying both Gini coefficient and Moran's I in distinguishing urban form, not only whether it is monocentric and polycentric, but also the compactness of centralized area and sub-area can be examined, thus making the classification between monocentric and polycentric clear of an area where the level of disproportion is obscure.

4. EMPIRICAL ANALYSIS

4.1. Description of Subjective Cities and Data

In this article, three major cities leading the development of Asia—Seoul, Tokyo, Beijing are selected as subjects of the analysis, since they are the capitol of Korea, Japan, and China, thus possesses significant positions in political, economical status. Taking all these properties into account, these cities can be the representatives in discussing about the establishment of eco-friendly urban form in Asia. Also, these cities represent the developed country—Japan, the nation entering the level of developed country—Korea, and the developing country—China, respectively. In

addition, reurbanization in Tokyo, desurbanization in Seoul, and suburbanization in Beijing is the significant tendency in each country. Therefore, it is hypothesized that these cities are adequate subjects to explain the correlation among urban development and change of urban form, and air pollution.

This research examined the changing tendency of urban form in the past 10 years (1997-2006) of the three cities through the Gini and Moran coefficient, which was gained from the utilization of the population and employment indexes. The objective is analysing not the general relationship between the urban form and air pollution, but the specialized correlation of the three cities by considering the particularities in urban form of respective cities. The data source such as population and employment indexes is the statistical yearbook of each city, and the analysis of Gini coefficient and Moran's I was performed with the distinctive data of population and employment. Also, by examining the tendency of variation of CO, CO₂—indexes representing the condition of air pollution and green-house gases, inquiry on the correlation among these factors was conducted.

4.2. Urban Form Analysis of Subjective Cities

While the total area of Seoul and Tokyo is similar, there is a difference in the area that is urbanized—95.85% in Tokyo, 69.92% in Seoul. However, the population density per urbanized area of Seoul is 1.7 times of Tokyo, 14 times of Beijing. Tokyo shows the most of possession of private transportation per person,

followed by Seoul, Beijing, in a sequence—the value of that of Beijing is approximately half of that of Tokyo.

In Beijing, 83.4% of the population is concentrated in four central districts, while the population in the eight major districts, including the central four, reaches approximately 97% of the total. However, the ratio of population and employment per the change in total population of the central four districts from 1997 to 2006 is showing decrease. Except for, the adjacent area Shijingshan, the ratio of change in population and employment of the four districts is in the tendency of increase, and the population and employment being expanded to the north and south part from the urban center.

In Tokyo, the change in population and employment shows a sharp difference. While the population tends to disperse towards the perimeter of the city, a re-concentration of employment in the old urban center is being observed. Thus, it is possible to verify that Tokyo has entered the re-concentration phase, the next level of concentration, sprawling phase.

Seoul shows the least concentration in the old urban center of population, and the population is increasing in the southern part. In the case of employment, three cores including the old urban center are formed, with the employment in the old urban center is decreasing, while the increase can be viewed in the perimeter around the cores.

In short, the urban form of Beijing is monocentric while a gradual change into polycentric form is in progress, an acceleration into spatial structure of polycentric

Table I: Basic Information of Beijing, Tokyo, Seoul

		<i>Beijing</i>	<i>Tokyo</i>	<i>Seoul</i>
<i>Area (Urbanized area)</i>	<i>km²</i>	<i>16410.54 (7236.30)</i>	<i>621.81 (596.02)</i>	<i>605.40 (423.28)</i>
<i>Population</i>	<i>1,000 persons</i>	<i>11,957.59</i>	<i>8,577.74</i>	<i>10,356.20</i>
<i>Density (Urbanized Density)</i>	<i>km²/1000 persons</i>	<i>0.73 (1.65)</i>	<i>13.79 (14.39)</i>	<i>17.11 (24.47)</i>
<i>Employment</i>	<i>1,000 persons</i>	<i>5,137.74</i>	<i>7,123.68</i>	<i>3,843.01</i>
<i>GNI</i>	<i>US \$2000 PPP</i>	<i>21,808.82</i>	<i>56,379.80</i>	<i>20,105.21</i>
<i>Passenger Vehicle Stocks</i>	<i>Per 1000 persons</i>	<i>122.49</i>	<i>269.70</i>	<i>233.52</i>

source: Asia Pacific Energy Research Center (2007)

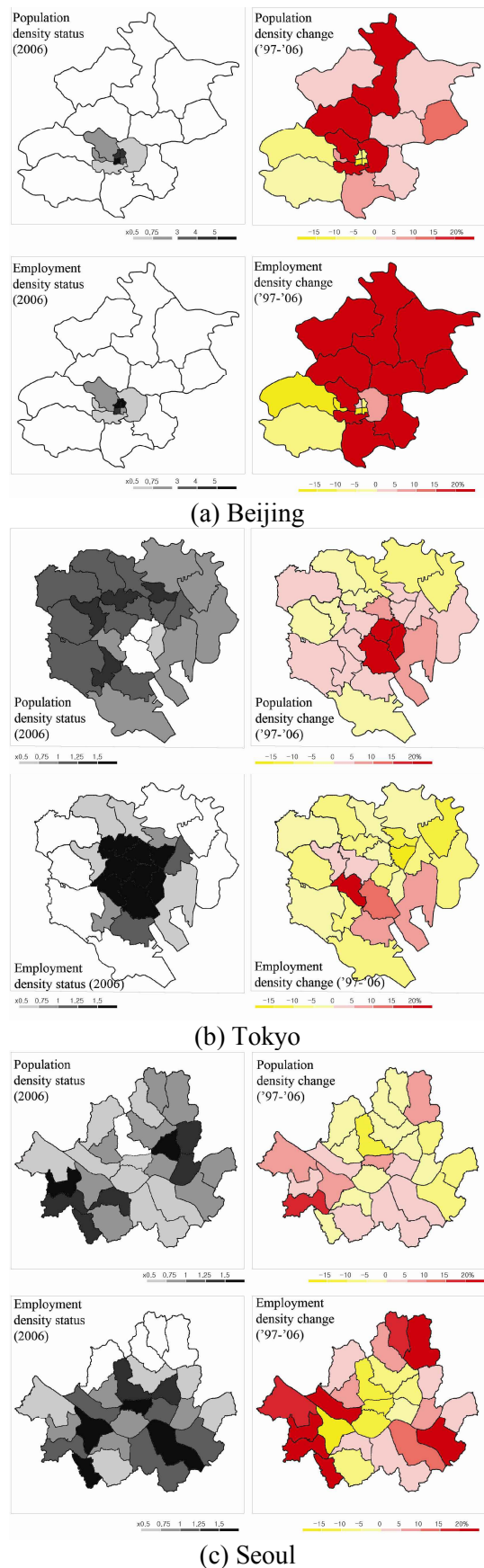


Figure 1: The Status and Change of Urban form of Subject Asian cities

form is occurring in Seoul, and the progress into the polycentric form is considerably advanced in Tokyo, thus a form of compact city in which employment is concentrated in certain old urban center is being observed.

The analysis on the Moran coefficient of the employment and population in these three cities shows the significant dispersion in population and employment of Beijing, compared to Seoul and Tokyo. In the case of Tokyo, the Moran coefficient of population is 0.06~0.065, and 0.02 in employment, indicating that the city is stabilized and possesses polycentric structure, and according to the past tendency, an advance into a compact monocentric form is in progress. In the case of Seoul, the Moran coefficient of population in the past 10 years ranges from 0.035 to 0.045, expressing a settlement into a polycentric form, while the Moran coefficient of employment varies around the value of zero, which can be discerned as a form of dispersion.

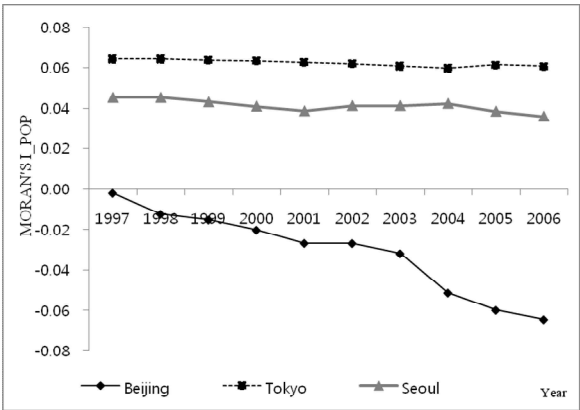


Figure 2: Changes of Moran's I (population)

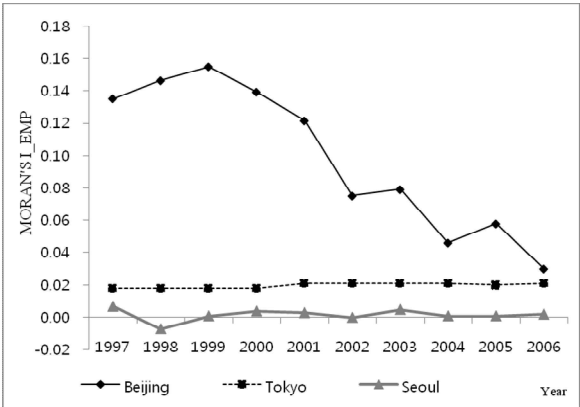


Figure 3: Changes of Moran's I (employment)

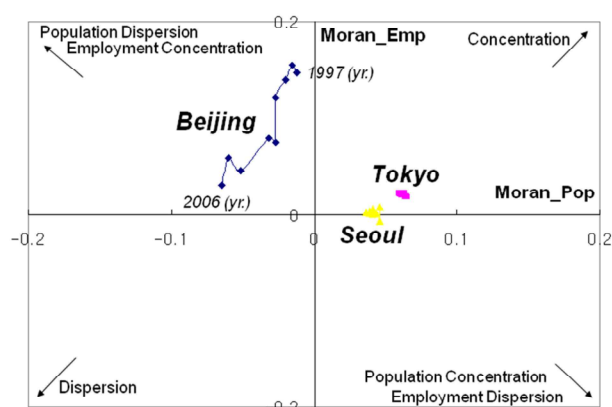


Figure 4: Spatial Changes of Three Cities Judged by Moran's I of Population and Employment

In summary, Beijing is in the phase of urban sprawl, Seoul is in a polycentric phase where the population is being concentrated while the employment is being dispersed, and Tokyo exhibits the traits of polycentric form, while a tendency of concentration of population and employment is viewed at the same time, thus can be judged as experiencing re-urbanization.

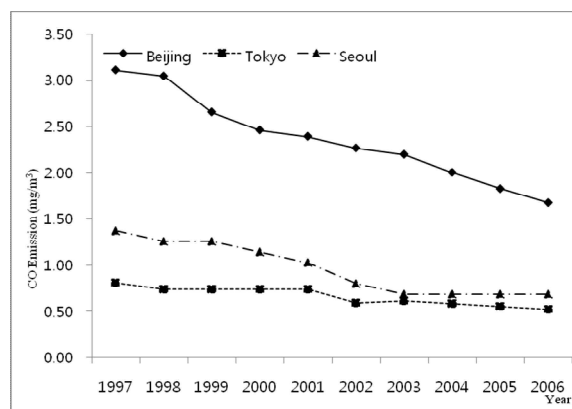
4.3. Correlation Analysis between Urban Form and CO/CO₂ Emission Index of Subjective Cities

In this research, the total emission of CO and CO₂ in the three cities from 1997 to 2006 is examined to draw out the correlation between the urban forms previously analysed, and the air pollution and greenhouse gas. In the case of CO emission which is controlled approximately 80% by motor vehicular transport, the annual total emission per unit area of the three cities shows the tendency of constant decrease.

According to the record, Beijing shows decrease from 3.11(mg/m³) of 1997 to 1.68 of 2006, and Seoul, from 1.37 to 0.69, and Tokyo, from 0.81 to 0.53. The 3.81 times gap between Beijing and Tokyo in 1997, had been shortened to 3.17 times as of 2006. Meanwhile, the 1.7 times gap between Seoul and Tokyo 10 years ago became only a slight difference in 2006.

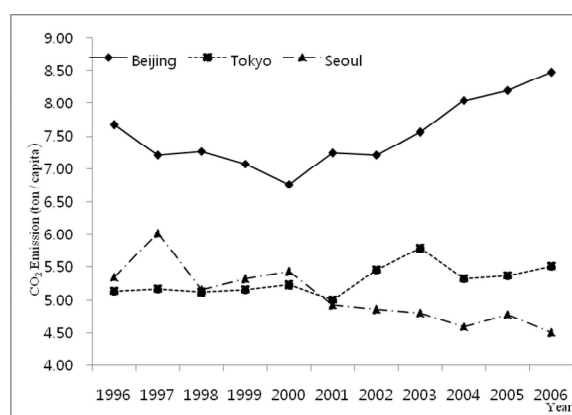
In the case of CO₂ that occupies approximately 95% of total greenhouse

emission, when converted into annual emission per population, Beijing records 8.47 ton per capita as of 2006 which is 1.5times higher than that of Tokyo and Seoul, while Seoul records the lowest, 4.50 ton per capita.



source: Statistics Bureau of Each Cities and Nations

Figure 5: CO Emission of Beijing, Seoul and Tokyo in 1997-2006



source: Statistics Bureau of Each Cities and Nations

Figure 6: CO₂ Emission of Beijing, Seoul and Tokyo in 1997-2006

When observing the tendency of CO₂ emission per population in the past 10 years from 2006, Beijing shows decrease until the year of 2000, but increase since then, and Tokyo exhibits stabilization of 5.0 ton per capita, and a slight increase to 5.5 ton per capita recently. In the case of Seoul, general decrease was shown since 1997, from 6.02 ton per capita to 4.5 ton per capita as of 2006.

In this research, the correlation of the Gini coefficient and the Moran's I is examined for the purpose of comprehending the relationship between the changing tendency of CO,

CO₂ emissions of the three cities in the past 10 years and the variation of urban form. As a result of the analysis, the correlation among the variables was at the level of 99%.

In the case of CO, the urban form index concerning population showed negative correlation (-0.874) with the Moran's I, and a positive correlation (0.923) with a Gini coefficient. Meanwhile, the urban form index concerning employment showed positive correlation (0.876) with the Moran's I, and a positive correlation also with a Gini coefficient (0.717).

Taking the overall results of the analysis in the correlation between CO and urban form indexes into account, the following implications can be drawn out. Firstly, as it is shown in the relationship with the population Moran's I, while emission of CO may decrease in a more concentrated urban form, CO and Gini coefficient shares positive correlation, thus a higher tendency of decrease is presented in an urban form of concentrated population with lower Gini coefficient, in other words, an urban form that possesses an area where population is apparently concentrated yet not holding a significant difference in the degree of concentration from other area. Similarly, since the total emission of CO shares a positive correlation with both the Moran's I of employment and the Gini coefficient, there is a higher tendency of decrease in the emission where the compactness of distribution of the employment area is harder and

the gap of concentration of employment with other area is broader.

In the case of CO₂, similar to the tendency of CO, the urban form index related to population shares negative correlation with the Moran's I (-0.914), and a positive correlation with the Gini coefficient (0.909). Also, the urban form index concerning employment shares positive correlation with both the Moran's I (0.677), and the Gini coefficient (0.812).

In the analysis of correlation with urban form indexes, the difference that can be pointed out between CO and CO₂, is that CO holds higher correlation with employment concerning the distinguishment among monocentric and polycentric urban form, while CO₂ possessing higher correlation with population. It is perceived that such properties contain certain connection with the fact that CO emission is controlled approximately 80% by transportation and conveyance field and that 30~40% of CO₂ emission come from conveyance field. To explain it analogically, lower level of CO emission can be possible in an urban form where the distance between the office and residence is close, which leads to lesser demand in vehicle usage in rush hour.

Linking this correlation among CO, CO₂ and urban form indexes with the result of the previous analysis of distinguishing urban forms, the respective values of Moran's I of the three cities remain in the range not exceeding 0.1. Therefore, an urban form in which the emission of CO and CO₂ decreases can be interpreted as a polycentric form where population is distributed relatively even over the entire city, and as a form with concentration of employment in monocentric or polycentric area.

5. CONCLUSION

Concerning the reduction of air pollutants in urban area, there is a necessity to focus on the 'urban growth management', the concept which is being actively studied in recent researches. An inquiry about the connection

Table II: Correlation between the Urban Form and Gas Emission Variables ($N=30$).

	<i>GE</i>		<i>Moran</i>		<i>Gini</i>	
	CO	CO ₂	Pop	Emp	Pop	Emp
<i>GE</i>						
CO						
CO ₂	0.81 *					
<i>Moran</i>						
Pop.	-0.82 *	-0.91 *				
Emp.	0.88 *	0.68 *	-0.64 *			
<i>Gini</i>						
Pop.	0.92 *	0.91 *	-0.97 *	0.79 *		
Emp.	0.72 *	0.81 *	-0.66 *	0.85 *	0.75 *	

* indicates a significant correlation coefficient at the 0.01 level. GE stands for gas emission

of the variation of urban forms with air pollution and green-house gas emission was performed in this research. Through the analysis on the correlation between respective urban forms of major Asian cities; Beijing, Seoul, Tokyo and the emission of CO and CO₂, the following results were obtained.

Firstly, Beijing used to hold monocentric urban form, but a gradual progress into polycentric form is in advance, a accelerated tendency of transition into polycentric spatial-structure is observed in Seoul, and the transition into polycentric form in Tokyo reached higher level, and traits of a compact city such as concentration of employment in the old CBD can be seen in certain area.

The analysis on the correlation between such change in the form of metropolitan and the emission of CO, CO₂, showed that urban form index concerning population shares negative correlation with them Moran's I, and positive correlation with a Gini coefficient. Also, urban form index concerning employment showed positive correlation both with the Moran's I and the Gini coefficient. Accordingly, the urban form with less CO, CO₂ emission is a metropolitan that has polycentric, spatially fairly clustered population, and compact employment distribution in the monocentric or polycentric area.

Implications on the future sustainable urban form drawn out from the result of this research may be summarized as follows.

First of all, as the result of assessment on three cities in different development phase respectively reveals, through the fact that improvement in CO and CO₂ emission in Tokyo is making a slow progress despite the tight urban compactness by reurbanization, a necessity for Seoul and Beijing to keep on the effort to establish polycentric urban form, which appears to be effective for reduction in CO and CO₂ emission can be underscored.

Secondly, for the purpose of establishing eco-friendly urban form that is effective for the reduction of air pollution and greenhouse gas emission, the development of a city is needed where the population is fairly distri-

buted, employment is concentrated in the polycentric area, and the concentration level of these areas is higher than the adjacent.

In conducting this research, some limitations such as not holding a further diversity in the set of Asian metropolitans, and the difficulty to examine both the urban development and the change in environmental policy at the same time can be pointed out. Certain complements to these aspects should be necessary in the further researches.

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